THE SEKHMET-HEKA HYPOTHESIS

Magic, Medicine & Memory: Shemsu Hor Predynastic Encoding

Zep Tepi Series — Supplementary Hypothesis to Paper III (Shemsu Hor Hypothesis)
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Abstract

"Magic is effective together with medicine. Medicine is effective together with magic."
— Ebers Papyrus, Eb 3 (c. 1550 BCE); Leitz 2005

The oldest surviving Egyptian medical texts are the most rational. The newest are the most magical. This is not what any developmental model of medicine predicts, and it is the organizing anomaly this paper addresses. The Kahun Gynaecological Papyrus (c. 1825 BCE) contains 34 purely empirical cases with no incantations. The Edwin Smith source text (c. 3000–2500 BCE) is rational in 47 of 48 surgical cases. The Ebers Papyrus (c. 1550 BCE) contains only 12 magical entries across 877 rubrics under minimal classification (rising to approximately 10–12% under broader Egyptological classification schemes; the inversion pattern holds under all schemes). The London Medical Papyrus (c. 1300 BCE) reverses this proportion: 36 of 61 prescriptions are classified as magical. If the unified Dynastic state invented systematic medicine, the newest texts would be the most sophisticated. The corpus runs in the opposite direction.

This paper proposes that the inversion is explained by inheritance rather than invention. A pre-literate pastoral knowledge system — gathered along the Saharan Highland Corridor during the terminal African Humid Period — was absorbed by the Dynastic state and progressively encoded within the theological framework of Heka. On this hypothesis, the botanical pharmacopeia was not lost but preserved within the theological framing; analysis of the 'magical' prescriptions confirms that plant ingredients are present intact throughout the entire corpus. What changed, on this reading, was the epistemological framing, not the medicine itself. The word Heka held empirical knowledge and divine explanation together without contradiction, because for the ancient Egyptians there was no contradiction to hold.

The knowledge trail follows corridor plants with confirmed or probable pre-unification presence in Egypt – the entire known Saharan/sub-Saharan component of the early Egyptian botanical record. All appear along the corridor; seven occur in the living Mauritanian pharmacopeia (six in Yebouk/Ehel Adja; *Lawsonia inermis* additionally in Thouzery 1997). *Commiphora africana* (myrrh), non-native to Egypt but native to the Sahel corridor, appears in both rational medical and magical ritual texts, mythologically encoded as Ra's tears (Salt Papyrus 825; Derchain 1964–1965) – a Late Period retrojection of a plant used for over two millennia. A peer-reviewed obstetrics study (Haimov-Kochman et al. 2005) independently identifies the knowledge source as 'herders of domesticated animals.' The 'magical' content in later texts represents progressive textualization of oral *heka* protocols that always accompanied pastoral treatment – not epistemological decline. All claims are bounded by explicit confidence classifications and falsification conditions.

Keywords: ancient Egyptian medicine, Heka, predynastic Egypt, Shemsu Hor, Saharan Highland Corridor, archaeobotany, ethnobotany, traditional ecological knowledge, Hierakonpolis, chronological inversion, Richat Structure

Author's Note

This paper is a supplementary hypothesis within the Zep Tepi Series, companion to The Shemsu Hor Hypothesis (Levy 2026c) and The Sphinx Hypothesis (Levy 2026e). Its central argument is that the Shemsu Hor — the Saharan pastoral population documented in Papers I–III — carried the botanical pharmacopeia of the Highland Corridor to Egypt, and that this transmission is consistent with the chronological and botanical evidence documented here and requires fewer additional assumptions than the alternatives considered in Section 11. Parsimony favours this explanation over its competitors; it does not by itself establish it. This is a hypothesis, not a proven account. The evidence presented is circumstantial and structural: chronological alignment, botanical distribution, linguistic fossils, and textual landscape memory. None of it constitutes direct proof of transmission. What it constitutes is a convergent case that the knowledge is structurally consistent with arrival alongside this population, framed explicitly as a falsifiable hypothesis under the methodological constraints of Section 3. The author holds no institutional affiliation. All citations were verified. Hypothesis language is used throughout.

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Series Context

The Zep Tepi Series documents a proposed northward migration by a Saharan pastoralist population — the Shemsu Hor — through a seven-node Highland Corridor Refugia during the terminal African Humid Period (c. 3800–3100 BCE). **Nodes**: the Richat Structure (Mauritania), Tassili n'Ajjer (Algeria), Takarkori/Tadrart Acacus (Libya), Messak Settafet (Libya), Gilf Kebir (Egypt), Nabta Playa (Egypt), and Hierakonpolis (Egypt). Papers I–III establish the geographic anchor, cultural grammar, and candidate population. The Sphinx Hypothesis (Levy 2026e) asks what this population built. This paper asks whether the botanical distribution of the oldest Egyptian medical pharmacopeia is structurally consistent with the corridor network. The paper follows the corridor's geographic sequence, from the proposed western terminus to the Egyptian destination.

The chronological alignment between the Shemsu Hor integration window and the Egyptian medical record is the organizing connection this paper makes explicit. Paper III (Levy 2026c) proposes the Shemsu Hor integration at Hierakonpolis within the 3800–3100 BCE window. The pre-papyrus archaeobotanical record documented in this paper places the corridor's medicinal plants in Egypt across exactly that range: castor oil in tombs at 4000 BCE; colocynth seeds at Naqada at 3800 BCE; Chemically Attested senna residue in pottery at 3150 BCE (compound-class identification, McGovern et al. 2009); Moringa from Old Kingdom tomb contexts (c. 2700–2181 BCE, immediately post-unification). All confirmed and probable pre-unification corridor plants tracked in this paper are present in Egypt before writing exists, before the state exists, and before any documented internal Egyptian mechanism could account for their presence in a systematic pharmacopeia — a pattern consistent with a model in which the pharmacopeia preceded the state rather than being invented by it. The Edwin Smith Papyrus source text — the oldest surviving Egyptian medical document and the most rational — is conventionally linguistically reconstructed to c. 3000–2500 BCE (Breasted 1930), based on hieroglyphic and hieratic word-forms more characteristic of earlier periods than the text's c. 1600 BCE copy date; an independent paleographic study of word-spellings across the 12th to 18th Dynasties reached a comparable early dating using a separate methodology (Dévaud 1924). However, the proposed range for the underlying composition is genuinely debated among Egyptologists: more recent analyses place the original anywhere from the end of the Old Kingdom to the early Middle Kingdom (Allen 2005; Sanchez and Meltzer 2012). Across this entire debated range, the source text substantially predates any documented internal Egyptian mechanism for inventing systematic rational medicine from scratch, and this paper does not rest on any single point within that range. Independent corroboration that Egypt's rational medical tradition has genuine Old Kingdom depth comes from two sources unconnected to Edwin Smith's own dating debate. Pommerening's (2014) classification of the broader Egyptian medical 'teaching text' genre, based on internal lexical and grammatical staging across the full corpus, dates the oldest stratum of that genre to the 5th/6th Dynasty, c. 2400 BCE. Separately, a skull excavated at Qau and dated to the very end of the Old Kingdom (7th–8th Dynasty, c. 2181–2160 BCE) shows a highly probable sign of therapeutic trepanation with a healed margin, consistent with sophisticated, survivable cranial surgery — the same domain Edwin Smith describes — being practised by this period (Fujita, Lee, Hong and Shin 2025). Before this broader window, no systematic Egyptian medical tradition is documented. After it, Egypt possesses the most sophisticated rational pharmacopeia in the ancient world, appearing fully formed in its oldest texts with no developmental record of invention. This paper proposes that this is consistent with knowledge arriving alongside this population rather than being invented from nothing.

What the Shemsu Hor built at Hierakonpolis, Paper III proposes. What the hypothesis proposes they may have carried — the botanical pharmacopeia of seven ecological zones traversed over generations — this paper traces. The paper's original contribution is twofold. First, building on the pattern noted by earlier scholarship (Reeves 2008 proposes differential preservation as one explanation for it; see Section 11), it proposes a specific mechanism for the chronological inversion — the progressive textualization of oral heka protocols — that this paper argues accounts for the pattern more fully than differential preservation does. Second, it demonstrates that the same corridor plants appear simultaneously across all Egyptian body-knowledge domains (medicine, perfumery, soap, hair care, textile cleaning, and embalming), and, applying discriminating tests from the cultural-evolution literature (linguistic, ancestry, and use) to this multi-domain simultaneity, argues that it is better explained by a unified pastoral knowledge system arriving intact than by separate institutional discoveries. This reframes the study of Egyptian medicine from a history of discovery to a history of preservation, and proposes that the oldest Egyptian medical texts are consistent with being the earliest documented record of an older pastoral pharmacopeia rather than the origin of systematic medicine. Given the paper's

interdisciplinary scope, readers may find the following navigation useful: the chronological inversion and Heka encoding mechanism are documented in Sections 1–2; the pastoral knowledge source and corridor network in Sections 4–5; the archaeobotanical and statistical evidence in Section 6; the ethnobotanical and ethnomusicological corridor record in Section 7; the One Medicine integration in Section 9; and the Equifinality Matrix and Falsification Conditions in Sections 11–12. Tables 1, 4, and 5 synthesise the pharmacological, archaeobotanical, and domain-mapping evidence respectively.

1. The Organizing Anomaly: The Chronological Inversion of the Medical Corpus

The oldest surviving Egyptian medical texts are the most empirically rational. The newest are the most theologically encoded. This chronological pattern is the opposite of what any model of progressive state-led medical development would predict, and it constitutes the organizing anomaly this paper addresses.

The evidence is direct. The Kahun Gynaecological Papyrus (c. 1825 BCE, UC32057, Petrie Museum; Griffith 1898) contains 34 cases that are entirely empirical, with no magical formulas or ritual instructions. The Edwin Smith Papyrus source text (linguistically reconstructed to c. 3000–2500 BCE; Breasted 1930) is rational in 47 of 48 surgical cases, describing the brain, meninges, cerebrospinal fluid, and heart-pulse relationship in clinical terms. The Ebers Papyrus (c. 1550 BCE), the largest surviving medical document with 877 rubrics, contains only 12 magical entries — approximately 1.4% magical content across the entire text. This count follows a minimal classification approach; Egyptologists disagree on what constitutes a 'magical' rubric. Grapow's classification (Grundriss der Medizin der Alten Ägypter, 1954–1973) identifies a larger number of heka-mediated entries depending on whether invocations accompanying botanical prescriptions are classified as magical content. Under broader classification schemes, the magical proportion of Ebers rises to approximately 10–12%. However, even at 12%, the inversion pattern holds: the London Medical Papyrus at 59% magical substantially post-dates Ebers, and the oldest texts (Edwin Smith source c. 3000–2500 BCE, Kahun 1825 BCE) remain near-zero magical under all classification schemes. The inversion is a robust pattern across the range of plausible classifications, not an artefact of minimal counting. Expressed as a Rationality Score (rational prescriptions ÷ total prescriptions × 100), the corpus-level trajectory runs from approximately 98–100% in the oldest texts (Edwin Smith source, Kahun) to approximately 41% in the London Medical Papyrus — a decline of approximately 57 percentage points. This quantified inversion is robust: even under the broadest magical classification scheme (Grapow 1954–1973, which raises Ebers to ~88–90%), the trajectory from oldest to youngest texts still shows a decline of approximately 47–49 percentage points. The pattern is not dependent on any particular classification methodology. A note on a divergent figure in adjacent literature: some general medical-history reviews outside Egyptology (e.g., Sallam 2010, citing Joachim 1890, Ebbell 1937, and Cunha 1949) report that Ebers contains "some 700 magical formulas." This figure is not derived from the Egyptological classification apparatus used here (von Deines, Grapow and Westendorf 1954–1973) and appears to conflate the papyrus's total prescription count — independently and consistently reported elsewhere as approximately 700–877 remedies — with its specifically magical-content subset; none of the three sources cited for that figure engages with Grapow's rubric-level classification. The 12–105-entry range used in this paper (1.4–12%, depending on classification breadth) is the one derived from primary Egyptological sources and is used throughout. A methodological note on the use of the rational/magical distinction: this distinction is used here instrumentally — not

because the ancient Egyptians recognised it, but because it tracks the progressive textualization of oral heka protocols across the documented corpus. The distinction is a modern analytical heuristic, not an ontological claim about Egyptian epistemology, and the percentage figures reported throughout this section should be read as approximate indicators of a real trend rather than precise measurements.

The Heka encoding model accepts, as its starting point, the Grundriss school's foundational insight that Egyptian medicine embedded empirical and divine explanation within a single cosmological framework; it uses the modern classificatory pattern as a proxy for the completeness of oral heka transcription — a tool that is valid precisely because it is anachronistic: earlier texts show the botanical core stripped of oral framing; later texts show the framing restored. The distinction measures how much oral content made it into the written record at different periods, not what the Egyptians themselves understood themselves to be doing. This observation was already noted in 1952: Leake, reviewing the full papyrus corpus, wrote of the Ebers Papyrus that 'it is remarkable that there is not more indication of magic and supernaturalism in the text' (Leake 1952, The Old Egyptian Medical Papyri, University of Kansas Press, p. 13) — an independent recognition of the same inversion pattern this paper formalises. Independent confirmation of the corpus's underlying medical validity, distinct from the rational/magical framing question, comes from a 2026 pharmacological review of the papyri corpus, which found that approximately 28% of described remedies retain therapeutic value by modern pharmacological standards (Ghalioungui 1987, The Ebers Papyrus: A New English Translation, Commentaries and Glossaries, Academy of Scientific Research and Technology, Cairo; cited in Khalpey, Amer and Abraham 2026, 'Decoding the Past, Informing the Future: Artificial Intelligence as a Bridge Between Ancient Egyptian Medical Knowledge and Modern Surgical Practice,' Cureus 18(3), DOI: 10.7759/cureus.104493). This figure measures genuine pharmacological efficacy rather than rational classification, and is therefore a separate, corroborating line: it confirms that real therapeutic content runs through the corpus independently of whether a given prescription happens to be framed in rational or magical terms. The inversion pattern documented here is independently consistent with the most recent comprehensive treatment of Egyptian medicine: David and Forshaw (2023, Medicine and Healing Practices in Ancient Egypt, Liverpool University Press, DOI: 10.3828/liverpool/9781837644292.001.0001) explicitly state that ancient Egyptians 'did not recognise a distinction between empirical-rational therapy and the use of incantations' and that 'both approaches were valid but had different applications for particular circumstances.' This is precisely the framework the present paper formalises: the Heka encoding model does not impose a modern rational/magical dichotomy but instead uses the modern classificatory pattern instrumentally to track the progressive textualization of what was, from the Egyptian perspective, a single unified therapeutic system. David and Forshaw further note that the Edwin Smith Papyrus is 'the oldest known' medical text and presents 'predominately rational therapies' in contrast to other papyri which 'are mainly lists of recipes or prescriptions, often incorporating a magical incantation within the text' — an independent confirmation of the chronological pattern this paper documents. The Grundriss der Medizin der alten Ägypter (von Deines, Grapow, and Westendorf 1954–1973) demonstrated that Egyptian medicine was embedded within a fundamentally magical-religious worldview, and that separating 'rational' from 'magical' content imposes an anachronistic distinction. The Heka encoding model accepts this as its starting point. Where the Grundriss school describes the end-state of integration — the fully encoded medical corpus — the Heka encoding model asks how that integration came to be. It proposes that the botanical core was inherited from a pastoral knowledge system, and that the theological framing was added progressively over centuries as the state absorbed and institutionalised that knowledge. The paper therefore does not challenge the Grundriss school's conclusions; it asks

a question the Grundriss school did not ask: what was the source of the botanical knowledge that the theological framework preserved?

Alternative Explanation: Multiple Coexisting Traditions and the Grundriss School A significant body of Egyptological scholarship argues that Egyptian medicine comprised multiple coexisting traditions — temple medicine, magical medicine, and what we might call surgical or rational medicine — that produced different types of texts for different purposes and audiences. The foundational statement of this view is the Grundriss der Medizin der alten Ägypter (von Deines, Grapow, and Westendorf 1954–1973), whose argument against separating 'rational' from 'magical' content is set out above; this section tests that premise against a specific rival account. More recently, Reeves (2008, Egyptian Medicine, Shire Publications) has argued that the apparent chronological inversion may reflect differential preservation: older rational texts survive because they were copied as core scribal curriculum in the Houses of Life, while magical texts were always produced in parallel but were preserved in temple contexts less likely to survive archaeologically. The Grundriss school's fundamental insight — that Heka united empirical and divine explanation within a single cosmological framework — is the starting point for this paper, not a position it argues against. The paper cites Grapow's classification counts directly. What the Heka encoding model adds is a mechanism: the Grundriss school describes the end-state of integration; this paper proposes how the integration occurred and why the botanical knowledge survived inside it.

The so-called magical prescriptions do not represent the loss of botanical knowledge. Analysis of the London Medical Papyrus confirms that 'spells are used together with the cures. Some of the texts outline what should be recited when a particular cure is being applied' (British Museum, London Medical Papyrus EA 10059). The botanical ingredient is preserved intact. The incantation specifies what to recite while the plant treatment is administered — not instead of it. The pharmacopeia survives inside the theological encoding.

The mechanism pattern within the corpus is instructive. Conditions with observable cause-and-effect relationships — anorectal diseases, surgical wounds, fractures — retained their rational character even in later texts. Chester Beatty VI (c. 1200 BCE), a specialist proctological treatise with 41 paragraphs, contains zero magical elements throughout, centuries after the London Medical Papyrus had become predominantly magical (Jonckheere 1947). Jonckheere's editor Jean Capart describes Chester Beatty VI in these terms: 'C'est vraiment de la doctrine, du raisonnement, c'est la transmission, à travers les générations, des résultats d'observations groupées suivant des principes' — 'This is truly doctrine, reasoning, the transmission across generations of observations grouped according to principles' (Jonckheere 1947, p. 9). Jonckheere himself classifies the London Medical Papyrus in footnote 6 as belonging to papyri whose medical content 'sont noyés dans des textes relevant de la magie' — 'are drowned in texts of magic' (p. 12) — a characterization entirely consistent with the inversion pattern this paper documents. Chester Beatty V (BM 10685), by contrast, uses magical formulae including a clay crocodile treatment for migraines — a condition whose mechanism was entirely invisible to pre-scientific observation (Gardiner 1935, Hieratic Papyri in the British Museum, Third Series). Chester Beatty VII (BM 10687) similarly relies on magical formulae against scorpion bites (Jonckheere 1947). The pattern is consistent: conditions with observable mechanisms retained rational treatment; conditions with invisible mechanisms attracted theological explanation. The knowledge was not lost. It was encoded in proportion to how mysterious the mechanism appeared.

Table 1 documents the chronological corpus with contemporary pharmacological validation. The column 'Character' follows conventional Egyptological classification; readers are directed to Section 2 for the reinterpretation of what 'magical' actually means in this context.

Papyrus	Date (BCE)	Cases	Character	Contemporary pharmacological validation
Kahun Gynaecological	c. 1825	34	Empirical, NO magic	Acacia contraceptive: triterpene saponin spermicide confirmed; still in modern contraceptive formulations
Ramesseum III–V (Gardiner 1955)	c. 1800	17+	Mixed, rational dominant	Post-partum Artemisia: same genus as 2015 Nobel Prize (Tu Youyou, artemisinin)
Edwin Smith (copy)	c. 3000–2500 BCE (linguistically reconstructed; copy c. 1600 BCE)	48	47/48 rational	Honey: antibacterial confirmed; mouldy bread: Nobel Prize 1945 mechanism (penicillin)
Ebers	c. 1550 (sources c. 1800)	877	Mixed	Willow bark → salicin → aspirin (precursor to the world's most widely used anti-inflammatory; Guinea-worm method unchanged to present
London Medical	c. 1300	61	25 medical, 36 magical	Rational layer preserved beneath increasing ritual overlay
Chester Beatty VI (anal treatise)	c. 1200	41	Purely rational, NO magic (specialized treatise)	Honey, myrrh, acacia, balanites, carob: all pharmacologically confirmed. "Systematic absence of magical infiltrations confers the value of a scientific document" (Jonckheere 1947)
Brooklyn	c. 450	Mixed	Mostly magical	Botanical ingredients preserved within magical formulae; individual plant pharmacological validation follows from the broader corpus documented above.

Papyrus	Date (BCE)	Cases	Character	Contemporary pharmacological validation
				Specific botanical pharmacology not reviewed for this table entry.

Table 1: Egyptian medical papyri in chronological order. The 'rational/magical' classification follows modern Egyptological convention but should be read with the following understanding: 'magical' prescriptions almost universally retain their botanical ingredients. The incantations specify what to recite while the plant treatment is applied — not instead of it. The inversion documented here is a general trend across the corpus, not a strict monotonic sequence. Chester Beatty VI (c. 1200 BCE), a specialised proctological treatise, contains zero magical elements throughout — post-dating the London Medical Papyrus (c. 1300 BCE) yet remaining purely rational. This is the expected pattern under the Heka encoding model: conditions with observable mechanisms (proctology, surgery, fractures) retained their rational character even in later texts; conditions with invisible mechanisms attracted theological explanation regardless of date. The inversion is therefore a pattern at the level of the corpus and subject-matter domains, not a year-by-year monotonic decline.

The Edwin Smith date column distinguishes surviving copy from linguistically reconstructed source date. The London Medical Papyrus magical proportion (59%) follows Ghalioungui (1963) and Wreszinski (1912); as with the Ebers Papyrus, classification schemes vary across Egyptologists. Under all plausible schemes, the London Papyrus is substantially more magical than Ebers, preserving the inversion pattern. Expressed as a Rationality Score (rational prescriptions ÷ total prescriptions × 100): Edwin Smith source ~98%; Kahun ~100%; Ebers ~99% (minimal) to ~88–90% (broader); London Medical Papyrus ~41%. The corpus-level trajectory is from ~98–100% rationality in the oldest texts to ~41% in the most magical later text — a decline of approximately 57 percentage points across the documented corpus. Chester Beatty VI (proctology, c. 1200 BCE, ~100%) confirms that subject-matter, not date alone, determined rationality in the later period.

2. The Explanation: Heka and the Encoding of Empirical Knowledge

Before examining the corridor evidence, the mechanism of the transformation documented in Table 1 must be established. Understanding how empirical knowledge becomes theological encoding is prerequisite to understanding why the botanical evidence looks the way it does.

The practical consequence is decisive. Jonckheere (1947, p. 39, footnote 2) documented four modes of magical infiltration in Egyptian medical texts: (1) magical formula joined as appendix to a complete botanical prescription; (2) magical formula inserted within the prescription; (3) magical formula preceding the treatment; (4) isolated magical formula with no botanical component. The first three modes preserve the botanical pharmacopeia entirely intact — only mode 4 represents pure incantation without physical treatment. The London Medical Papyrus (BM EA 10059), the most magical text in the corpus, contains 61 prescriptions of which 25 (41%) are classified as rational and 36 (59%) as magical (Wreszinski 1912; Ghalioungui 1963, Magic and Medical Science in Ancient Egypt). Of those 36 magical prescriptions, the majority involve botanical ingredients combined with incantation (modes 1–3); only a minority are pure

incantation with no physical treatment (mode 4). The plants never left. The theological framing arrived around them.

The mechanism for why incantations were added is documented in the texts themselves. The Ebers Papyrus states explicitly: ‘Magic is effective together with medicine. Medicine is effective together with magic.’ The Sais inscription, cited in multiple histories of ancient Egyptian medicine including Nunn (1996, Ancient Egyptian Medicine, British Museum Press), records a physician stating: ‘I have come from the school of medicine at Heliopolis, and have studied at the woman’s school at Sais, where the divine mothers have taught me how to cure diseases.’ Medicine and divine teaching are the same activity, described in the same breath.

The integration of botanical knowledge into theology is most clearly illustrated by the Salt Papyrus 825 (BM 10051; critical edition: Derchain 1964–1965), a Late Period text (c. 700–300 BCE). The text records that when Ra wept during creation, his tears fell to earth and became myrrh — Commiphora resin, with confirmed antimicrobial, anti-inflammatory, and analgesic properties. This is not evidence of the original encoding moment; Commiphora was in Egyptian use by at least 1825 BCE (Kahun Papyrus) and in Chemically Attested pre-papyrus archaeobotanical contexts from c. 3000 BCE (compound-class identification; species-specific identification pending, see Section 6 Statistical Summary). What the Salt Papyrus documents is the end-state of a process that had been running for millennia: a plant whose healing worked was given a divine explanatory origin, because the biochemical mechanism was invisible to pre-scientific observation. The theological retrojection confirms that the encoding mechanism operated continuously across Egyptian history — not that it was invented at the Late Period. The plant healed. The god got the explanatory credit. The encoding mechanism documents the pattern; the Late Period text shows it still operating thousands of years after the original integration.

The implication for reading the inversion: the oldest papyri — Kahun, Edwin Smith — preserve the botanical pharmacopeia before the institutional theological encoding was complete. The later papyri preserve the same pharmacopeia with the theological framing fully developed around it. The Brooklyn Papyrus, at its most ‘magical,’ still documents the botanical treatments used alongside the ritual protocols. The knowledge was never lost. The Heka framework is not evidence of decline. It is evidence of institutionalization.

Sekhmet is a lioness. This connects the medical tradition to the iconographic argument of the Zep Tepi Series. The Sphinx Hypothesis (Levy 2026e) proposes that the same corridor population carried the lion iconographic tradition. If that hypothesis is accepted, the medical and iconographic arguments share a common proposed origin population, though each paper stands independently on its own evidence. The lioness who heals is iconographically consistent with the same lion tradition — a convergence documented as a series-level observation in Phase Zero (Levy 2026d). Different domain, the same proposed origin population — each paper in this Series stands independently on its own evidence; the convergence is noted across the Series, not claimed within this paper.

Sekhmet’s domain is both plague and cure. Bestetti et al. (2024) argue that her priests performed the first documented recognition of zoonotic disease transmission, though this interpretation is not consensus Egyptology and may equally reflect ritual purity concerns. She is associated with Lower Egypt — the corridor’s geographic destination. Her priests were the first formally identified physicians. This is a suggestive reading consistent with the corridor hypothesis; the symbolic system and the epidemiological reality are distinct: the iconographic connection is noted as a series-level observation consistent with the corridor hypothesis; the paper does not claim it as primary evidence, and the companion Sphinx Hypothesis (Levy

2026e) addresses the iconographic argument independently. Heka is the word that names the transformation: what was botanical knowledge became religious practice; what was pastoral observation became institutional medicine.

Heka — Magic and Medicine as One

The word ḥkꜣ (Heka) is simultaneously the Egyptian word for magic, the name of the god of magic and medicine, and the name of the primordial creative force, existing before the gods themselves and the source of their power (Coffin Texts, Spell 261), through which ritual and healing action was believed to work. This triple identity is the most direct evidence that the ancient Egyptians never separated what modern scholars have called 'rational medicine' from 'magical medicine.' They were the same thing, described by the same word, governed by the same god and the same force. As peer-reviewed scholarship states: 'A priest treating a sick person might recite an incantation, apply an herbal remedy, and make an offering to a god, all as part of the same treatment. None of these steps would have seemed more rational or superstitious than the others' (Ritner 1993, The Mechanics of Ancient Egyptian Magical Practice, SAOC 54). This integration is confirmed independently in peer-reviewed medical history: 'The border between magic and medicine is a modern invention; such distinctions did not exist for ancient healers' (Karenberg A. and Leitz C. 2001, 'Headache in magical and medical papyri of ancient Egypt,' Cephalalgia 21(9): 911–916). The incantation and the herb were not in competition. The incantation explained the mechanism — divine force — while the herb enacted it. When this paper's evidence base shows corridor plants appearing in both the oldest empirical papyri and the later 'magical' papyri, it is because the botanical pharmacopeia was never displaced. What changed was the institutional theological framing applied on top of it. The Heka hypothesis — encoded in this paper's title — names exactly this: the word Heka held the empirical and the divine together without contradiction, because for the ancient Egyptians, there was no contradiction to hold.

Egyptian royal ideology paired two practices that are easy to conflate but lexicographically distinct, and the distinction matters for what this paper can and cannot claim. The crook-sceptre carried by Egyptian rulers and gods (Gardiner sign S38) represents the word ḥqꜣ, 'ruler,' the root also underlying ḥqꜣw ('ruler/king') and ḥqꜣt ('ruler's domain,' hence 'nome'), written with q rather than k in standard Egyptological transliteration (Wb. III 175). Heka, the divine force of magic and medicine, is ḥkꜣ, written with the ka-arms sign (Gardiner D28) and the consonant k — a separate Wb. III lemma (Erman and Grapow 1926–1961, Wb. III 175). Wilkinson (1992, Reading Egyptian Art, Thames and Hudson, pp. 188–189), Meeks and Favard-Meeks (1996, Daily Life of the Egyptian Gods, Cornell University Press, pp. 36–38), and Allen (2010, Middle Egyptian, 2nd ed., Cambridge University Press, §8.2) all maintain this distinction; none of them treats the crook-word and the magic-word as a single etymological root, and this paper does not claim that they cite otherwise. What the crook-sceptre and heka share is not a shared root but a documented ideological pairing in royal theology. Ancient Egyptian texts make frequent use of paronomasia — deliberate wordplay between phonetically similar terms — and the near-homophony of ḥqꜣ and ḥkꜣ is a documented instance of this practice: the king's ruling authority was rhetorically and symbolically bound to the primordial power he wielded, even though the two words derive from different roots. The earliest known royal crook is dated to the Gerzeh culture (Naqada II, c. 3500–3200 BCE) and was recovered from tomb U-547 at Abydos, documenting the evolution of a functional pastoral implement into elite ceremonial regalia across the predynastic integration window. The pastoral origin of the physical object is independent of the etymological question: a corridor population that herded with the crook is consistent with the artefact's later adoption as royal regalia, regardless of whether its name shares a root with the word for magic. This paper's argument therefore rests on two separable

claims — the documented pastoral-to-regalia trajectory of the crook itself, and the well-established single root of heka as magic, medicine, and divine name (Ritner 1993; Karenberg and Leitz 2001; Zucconi 2007, all cited above) — not on a claimed shared etymology between the two. Zucconi (2007, 'Medicine and Religion in Ancient Egypt,' Religion Compass 1: 26–37, DOI: 10.1111/j.1749-8171.2006.00004.x) independently frames heka not as superstition but as a technical term for effective force — 'power' — the activating principle that makes a remedy work, with heka functioning as 'power' required to restore maat (balance). Under this reading, heka in medicine is not the opposite of empirical knowledge; it is its mechanism-name, applied to effects whose biochemical basis was unavailable to pre-scientific observation. The pastoralist knew the plant healed. The word heka named why it healed.

The so-called 'magical' prescriptions are therefore more precisely understood as oral protocols — structured speech acts encoding the remedy, the condition, the application sequence, and the attribution of mechanism in a single utterance designed to survive transmission intact across pre-literate generations. Egyptological scholarship has recognised that two types of practice coexisted in ancient Egypt: an intuitive, improvised knowledge transmitted orally, and a literary tradition in which formulae became fixed so that their exactness and antiquity were thought to give them power (Pinch, G. 1994, Magic in Ancient Egypt, British Museum Press, London, p. 9). The first — oral, improvised, transmitted — is the functional description of how a pastoral pharmacopeia survives across pre-literate generations. The second — fixed, exact, ancient — is what the scribes of the Houses of Life codified when they absorbed that oral tradition into the institutional record. This reading extends the corpus-level inversion documented in Section 2. The oldest surviving papyri are the most rational because the earliest scribes transcribed the botanical knowledge stripped of its oral framing: the herb, the dose, the condition, without the incantation-wrapper that the pastoral knowledge-holder always recited alongside the treatment. The later texts, with proportionally more 'magical' content, may represent a fuller transcription of the original oral protocols, complete with the spoken formula. The knowledge was the same throughout. What changed was the completeness of transcription. The pharmacopeia did not become more magical across time. The scribal record of it became more complete.

A convergence that falls outside the primary scope of this paper but is documented here for series context: the curved shape of the crook-sceptre — a hook on a handle — belongs to the same functional shape class as the ceremonial adze used in the Opening of the Mouth ceremony, whose form independently matches the Meskhetyu asterism (Ursa Major, the Bull's Foreleg). The peer-reviewed literature confirms that the Egyptian concept of Ursa Major as a rejuvenation symbol and a potent force associated with the Opening of the Mouth ceremony may date to the beginning of the Predynastic period, c. 4000 BCE (Relke, J. and Ernest, A. 2002–2003, 'Ancient Egyptian Astronomy: Ursa Major — Symbol of Rejuvenation,' Archaeoastronomy: Supplement to the Journal for the History of Astronomy Vol. XVII: 64–80). The Phase Zero paper of this Series (Levy 2026d) proposes the full chain: the corridor pastoralists who watched the hook-shaped circumpolar stars from Nabta Playa (c. 4600–3400 BCE) named them Meskhetyu — the Bull's Foreleg — for the most symbolically charged animal part in their pastoral world; the ritual adze was subsequently shaped to match those stars; and the architectural orientation of the provincial pyramid at el-Kula encodes Meskhetyu at the precise latitude where the constellation reaches its circumpolar threshold. The shepherd's crook, the ritual adze, and the hook-shaped constellation are the same shape, held by the same population, across three institutional domains: medicine, ceremony, and astronomy. This is a convergence of form and population, not of etymology: the crook-word (ḥqꜣ) and the magic-word (ḥkꜣ) remain lexicographically distinct, as established above. Each paper in this Series documents one domain independently; the convergence is noted here as a series-level observation that this paper does not independently verify.

Heka and the Unified Botanical Domain

The preceding sections have argued that heka unified what modern scholarship separates into medicine, magic, ritual, and religion. That argument carries a methodological consequence for the botanical evidence base of this paper. If heka governed all botanical knowledge simultaneously — the prescription in the Ebers Papyrus, the incantation in the London Medical Papyrus, the incense formula in the temple laboratory, the funerary offering in the predynastic tomb — then restricting the corridor plant count to the medical papyri alone imposes exactly the categorical distinction this paper argues did not exist. The corridor pastoralists who carried botanical knowledge to Egypt did not arrive with separate inventories labelled 'medicine' and 'ritual'. They brought integrated knowledge of plant properties, encoded across multiple application domains within the single framework of heka. Counting only plants that appear in the medical papyri undercounts the evidence by the same magnitude as the distinction the paper argues is a modern invention.

The clearest demonstration of this principle is kyphi (Egyptian: kapet) — the sacred compound incense first attested in the Pyramid Texts, with its earliest surviving recipe in the Ebers Papyrus itself (c. 1550 BCE), and its full New Kingdom formula recorded in the Harris Papyrus (Ramesses III, c. 1184–1153 BCE) and inscribed on the temple walls of Edfu and Philae. Kyphi was simultaneously a ritual offering burned to the gods, a therapeutic preparation taken orally for asthma and administered by inhalation for respiratory conditions (Dioscorides, De Materia Medica; Plutarch, De Iside et Osiride), and an antimicrobial fumigant whose efficacy has been confirmed in independent peer-reviewed laboratory testing (Maravelia, Faviou and Filianos 2022, Aegyptus et Pannonia VIII; Faviou, Magiorkinis, Maravelia and Filianos 2023, Journal of the Hellenic Institute of Egyptology 6). The Ebers Papyrus — the paper's primary source for the rational medical corpus — contains kyphi's earliest recipe. Temple inscriptions — explicitly described by Ritner (1993, SAOC 54) as the material dimension of the same heka practice that produced the medical papyri — contain its most complete documentation. There is no evidentiary or methodological reason to exclude kyphi ingredients from the corridor botanical inventory. They are in the Ebers Papyrus. They are in the heka tradition. They are in the same knowledge system.

Broadening the evidentiary base from medical papyri to the full heka botanical domain recovers a confirmed corridor plant whose arrival timing requires careful treatment: Cymbopogon schoenanthus (L.) Spreng. (camel grass, aromatic rush; syn. Andropogon schoenanthus L.), a core ingredient in the kyphi formula. Its native range is documented by the Royal Botanic Gardens, Kew (Plants of the World Online: powo.science.kew.org/taxon/397010-1) as extending from North Africa (Mauritania) eastward to Egypt, Sudan, and Arabia — the Mauritania-to-Egypt arc that defines the corridor. It is not native to Egypt: its distribution is North African and Sahelian, placing it in the same non-native corridor category as Commiphora africana. It was identified in the kyphi formula as 'aromatic rush' (Andropogon schoenanthus) by Manniche (1989, An Ancient Egyptian Herbal, pp. 159–162) and confirmed by McGovern et al. (2009, PNAS 106(18): 7361–7366, citing Nunn 1996, pp. 211–212, Appendix B). Physical plant remains of Cymbopogon schoenanthus have been identified in ancient Egyptian tombs, documented by Schweinfurth (1883, 'The Flora of Ancient Egypt,' Nature 28: 109–114; 1884, 'Further Discoveries in the Flora of Ancient Egypt,' Nature 29: 312–315) and cited authoritatively in Burkill (I.H. 1935, p. 728). The tomb finds documented by Schweinfurth date to the 21st Dynasty (c. 1070–945 BCE) at Deir el-Bahari. The Ebers Papyrus kyphi recipe (c. 1550 BCE) constitutes the earliest textual attestation of it as a named ingredient. However, kyphi itself — as a compound preparation — is named in the Pyramid Texts of the Old Kingdom (5th–6th Dynasties, c. 2400–2300 BCE), placing its use before any surviving recipe specifies its

ingredients (Manniche 1999, Sacred Luxuries, p. 55).

Since camel grass is a documented core ingredient in every surviving kyphi recipe across all periods, and since the plant is non-native to Egypt and corridor-distributed, its presence in Egypt by the Old Kingdom is the most parsimonious inference — though no pre-unification physical find has been confirmed at current evidence levels. On this basis Cymbopogon is classified as an Old Kingdom corridor arrival with transmission inference: non-native to Egypt, corridor-distributed, attested in Egypt from the Old Kingdom period via the kyphi preparation, with arrival most plausibly connected to the corridor population. This places it in a separate sub-category alongside Moringa oleifera — distinct from both the seven confirmed pre-unification taxa (which have physical or chemical evidence predating 3100 BCE) and the three late post-unification trade arrivals (Hibiscus, Acacia senegal, Tamarindus). The statistical proportions remain 7/21 = 33% (of all 21 identified pre-unification taxa) and 7/15 = 47% (of the 15 taxa non-native to Egypt specifically). Both denominators are small, and no null expectation — the proportion of corridor-distributed taxa expected by chance given Egypt's ecological position — has been independently calculated; these percentages describe the current record, not a statistically tested departure from a baseline. Its active compounds include terpenes, flavonoids, and essential oils with documented spasmolytic, antimicrobial, and anti-inflammatory activity (Pavlović, Omar et al. 2017, Archives of Biological Sciences 69(3): 409–415). In the Timbuktu-Mali region — within the same Sahelian pastoral zone the corridor traverses — it is documented in gynaecological treatment, labour support, post-partum care, and digestive conditions: the same application domains as the seven confirmed pre-unification corridor plants. In Sudan — corridor Node 6-adjacent — it is documented in traditional pharmacological use from Khartoum state (Mokhtar et al. 2023, Life 13(7): 1451, DOI: 10.3390/life13071451).

The Heka encoding model can be formalised as a set of testable propositions.

- **Proposition 1:** A pastoral knowledge system, transmitted orally, encodes botanical properties as integrated multi-domain knowledge (medicine, hygiene, fragrance, preservation) rather than as separate specialised applications.
- **Proposition 2:** When this knowledge system is absorbed by an institutional state, the botanical content is preserved while the oral framing (incantations, spoken protocols) is progressively textualized over centuries.
- **Proposition 3:** The textual record will therefore show (a) early texts prioritising botanical content over framing, and (b) later texts including increasingly complete framing, producing the chronological inversion documented in Section 1.
- **Proposition 4:** The same botanical suite will appear across all institutional domains that preserve pastoral body-knowledge (medicine, perfumery, cosmetics, embalming) because they derive from a single knowledge tradition, not from separate institutional discoveries.
- **Proposition 5:** Corridor plants absent from any of these domains should be predictable from their absence in the pastoral source tradition or from ecological substitution by Nile Valley alternatives — not from random omission. These propositions generate the predictions in Section 10, all of which are testable against the existing papyrus and archaeobotanical record. They also generate a framework that other scholars can apply: any pre-literate pastoral knowledge system absorbed by an institutional state should, on this model, produce the same inversion pattern in its earliest textual records — a comparative prediction that extends the hypothesis beyond Egypt.

3. Methodological Framework

A note on the scope of genetic evidence in this paper. The genetic foundation of the corridor model — the chain from Taforalt (Morocco, 15,000 BP) through Takarkori (Libya Fezzan, 7,000 BP; Salem et al. 2025) to the Nuwayrat Old Kingdom genome (2855–2570 BCE; Morez Jacobs et al. 2025) — is argued and defended in Papers I and II of this series (Levy 2026a, 2026b), building on the externally peer-reviewed genetic findings of Salem et al. (2025) and Morez Jacobs et al. (2025). This paper adopts the corridor model developed in Papers I and II as its working framework and does not re-argue the genetic case; the peer-reviewed genetic findings themselves are treated as established, but the corridor-transmission interpretation built on them remains, as in Papers I and II, a hypothesis rather than a settled conclusion. The genetic evidence is relevant here in one specific, bounded way: Salem et al. (2025) establish that the Takarkori lineage's closest ancient affinity is to Taforalt (Morocco), and its modern echoes split geographically into two branches: a southward branch into Fulani populations across the Sahel (D'Atanasio et al. 2023; Fortes-Lima et al. 2025), and a branch that remained in the Maghreb/western Sahara, carried most strongly by Saharawi and other Berber-speaking populations (Serra-Vidal et al. 2019) — the same broad ethnolinguistic population as the Hassaniya-speaking Bidhan/Haratine communities whose pharmacopeia this paper traces botanically. No study has directly compared the ancient genomes to modern Saharawi or Mauritanian samples, so this link remains circumstantial rather than confirmed (see Section 9). This paper makes no independent claim about genetic directionality; that argument belongs to Papers I and II.

The argument of this paper is consilient: it draws on independent evidence from Egyptology, archaeobotany, ethnobotany, linguistics, genetics, and pharmacology. No single line of evidence proves that the Shemsu Hor transmitted the corridor pharmacopeia to Egypt. The concept of consilience of inductions, first formalised by Whewell (1840) and revived by Wilson (1998), holds that when independent lines of evidence from different domains converge on a single explanation, that convergence itself constitutes a stronger inferential warrant than any single line could provide. The evidence is presented domain by domain so that readers from each discipline can evaluate it within their own methodological standards; the Equifinality Matrix (Section 11) maps whether the convergence is better explained by transmission or by the alternatives. The botanical and chronological evidence is the paper’s primary load-bearing argument. The archaeobotanical, ethnobotanical, and pharmacological lines are independent corroborating evidence in the sense that matters here: their documentation does not require the corridor model to be true. The genetic and linguistic lines corroborate aspects of that same corridor model as established in Papers I–III, rather than testing it fresh; each contributes what it can, none is asked to carry more than it can demonstrate, and the convergence across the independent lines, supported by the corroborating ones, is the case. A note on why convergence constitutes evidence and not merely coincidence. Shared plant distribution does not by itself imply knowledge transfer rather than repeated local discovery or parallel ecological access. The answer this paper gives is cumulative and structural, not singular.

First (Egyptology), the relevant plants appear in the oldest surviving Egyptian medical texts (Kahun, Edwin Smith) before any state-level mechanism for acquiring them is documented, and the chronological inversion of the corpus itself is explained by progressive Heka encoding (Section 2) rather than differential preservation.

Second (archaeobotany), the relevant plants are non-native to Egypt and corridor-distributed, directly attested by physical remains at the Takarkori pastoral node (di Lernia et al. 2024) and in Egypt itself before unification.

Third (ethnobotany), the Commiphora africana tracking data — pastoral herders following the plant's seasonal leaf cycle as a grazing guide (Le Houerou 1980) — provides a concrete mechanism by which accumulated knowledge would accompany population movement rather than remaining stationary, corroborated by the continuity of the same applications in the contemporary Mauritanian pharmacopeia (Yebouk et al. 2020, 2026).

Fourth (linguistics), the adr- root persists as a cognate name across six corridor populations (Section 7), evidencing that the source tradition was linguistically continuous rather than independently coined at each node, though this evidence does not itself bridge into ancient Egyptian.

Fifth (genetics), the genetic evidence (Salem et al. 2025) documents deep ancestral continuity from the corridor nodes into a modern population whose range includes the western terminus, via a two-branch pattern detailed in Section 9; this link is circumstantial rather than confirmed.

Sixth (pharmacology), the applications match across the corridor — same plants, same conditions, same application domains — in a pattern more specific than general ecological availability would predict, and each application is independently confirmed by modern pharmacological review (Section 6). No single one of these lines is decisive.

Together, across six independent disciplines, they converge on a population-transmission explanation that is more parsimonious than the alternatives because it requires no additional mechanisms beyond the documented ones: a pastoral population moving through the habitat zone of the plants it used, carrying that knowledge to the Nile. One limitation on this convergence should be stated plainly: the genetic and linguistic lines do not stand fully independent of the corridor model itself, since the population movement they corroborate is established in Papers I–III rather than argued fresh here (this paper makes no independent claim about genetic directionality; see Section 4). The archaeobotanical, ethnobotanical, and pharmacological lines are independent of that prior argument in the sense that matters here — they do not require the corridor model to be true to be individually documented — and it is primarily their convergence with each other, not with the genetic and linguistic evidence, that carries the weight of the consilience claim. The Equifinality Matrix (Section 11) maps each alternative explanation's evidential problems in detail; this paragraph consolidates the argument that the matrix develops. Parsimony comparison. The transmission hypothesis requires three assumptions: (1) a pastoral population moved through the corridor; (2) they carried botanical knowledge with them; (3) that knowledge was absorbed by the Dynastic state. Each is independently documented: population movement (Zep Tepi Series Papers I–III; Salem et al. 2025, Nature), botanical knowledge in the corridor zone (Hammiche and Maiza 2006; di Lernia et al. 2024; Thouzery 1997, 2002), and institutional absorption (Bestetti et al. 2024; Gardiner 1938).

The alternative hypotheses require additional unverified assumptions: independent Nilotic discovery requires that multiple non-native plants were independently identified with the same multi-domain applications across Egypt and the corridor without transmission — a series of coincidences for which there is no independent evidence; trade network transmission requires that the pre-unification medicinal suite was acquired through elite exchange channels despite its functional, non-prestige character; preservation bias requires systematic loss of magical content from the oldest texts despite the Houses of Life copying tradition. The transmission hypothesis requires no additional mechanisms beyond the documented ones. The alternatives each require at least one specific, independently unverified mechanism to explain the same evidence.

Parsimony therefore favours the transmission hypothesis. A related alternative deserves explicit treatment: that the corridor pharmacopeia was transmitted through trade or cultural contact without any population movement. Two features of the evidence favour population movement over trade-only transmission.

First, the medicinal suite is a multi-domain system — the same plants appear across medicine, perfumery, soap-making, hair care, and embalming simultaneously. Trade typically transmits individual commodities, not integrated knowledge systems. A pastoral population arriving with the full body-knowledge system explains the simultaneous appearance across all domains; trade-only transmission requires that each domain was acquired separately, which is less parsimonious. Second, the most efficient mechanism for transmitting the integrated knowledge of a plant's multi-domain properties is the movement of the people who hold that knowledge. Trade can transmit goods; it cannot transmit the understanding that the same plant is simultaneously a soap, a perfume carrier, a molluscicide, and a medicine — unless the traders also hold that knowledge, in which case they are functioning as knowledge carriers rather than mere traders. The corridor model does not require that trade was absent; it requires that the primary transmission mechanism was population movement, with trade playing a secondary role in the post-unification period.

The argument in this paper is also a constraint-satisfaction framework over documented botanical co-occurrence and ecological continuity. This section states the constraints explicitly so that the paper's epistemics are transparent throughout.

Definitions

Ecological Continuity Edge (E_eco): A documented shared biome, habitat connection, or archaeobotanical presence relationship between two nodes. Undirected. Does not imply transmission, diffusion, or cultural exchange.

Temporal Ordering Edge (E_seq): A chronological sequence between two nodes. Directed. Does not imply causal transmission; direction is temporal only.

Confidence Class: Qualitative evidentiary strength based on current Tier A literature and archaeological sampling density. High / Moderate / Low. Low confidence reflects sampling limitations, not confirmed absence. Untested: no archaeological, chemical, or genetic study has been conducted on this specific claim. Distinct from Low, which reflects thin but existing evidence; Untested reflects the absence of evidence-gathering itself, per Axiom 5.

Six Methodological Axioms

Axiom 1: Correlation does not imply transmission. Shared botanical distribution is consistent with, but does not establish, knowledge transmission.

Axiom 2: Ecological continuity does not imply diffusion. E_eco does not imply E_seq.

Axiom 3: Temporal ordering does not imply causal transmission. E_seq is chronological sequence only.

Axiom 4: No temporal ordering edges for medicinal plants in the pre-3000 BCE period. Only E_eco edges are claimed for this period.

Axiom 5: Absence of evidence is not evidence of absence. For under-excavated regions — particularly Mauritania/Western Sahara — current absence of archaeobotanical evidence reflects sampling density, not definitive proof of absence.

Axiom 6: Edge clustering does not imply latent structure.

Sampling Asymmetry

Three of the four rows below answer the same question — how confident is the evidence that these plants were present or used at this node — and are rated on the standard High/Moderate/Low scale. The Richat zone answers a second, harder question that the other three nodes are not asked: whether this is specifically the corridor's point of origin, not merely a waypoint. No archaeological, palynological, or residue study has ever been conducted at the Richat zone for the pre-3000 BCE window; the origin question is therefore rated Untested, not Low — a category distinct from thin evidence, reflecting the absence of any attempt to gather evidence at all (see the Confidence Class definitions above and Prediction 11). The zone's participation in the corridor pattern — whether its documented plant use matches the corridor's botanical suite — is a separate, answerable question, and is rated Moderate on existing ethnobotanical and historical survey evidence.

Region	Sampling density	Confidence impact	Class (this paper)
Egypt (Nile Valley)	High	Reliable presence data	High
Libya/Algeria (Tassili, Takarkori)	Moderate	Good confidence	High–Moderate
Sudan/Nubia	Moderate-High	Good confidence	Moderate-High
Mauritania/ Western Sahara (Richat zone)	Low	Absence ≠ evidence of absence (Axiom 5)	Untested — Prediction 11 (origin) / Moderate (participation)

Table S1: Sampling density and confidence class by region. Mauritania has the lowest excavation density of all corridor nodes. Confidence assessments are conservative and subject to upward revision on future fieldwork.

Seven plants shared between the Mauritanian pharmacopeia and Egyptian medicine establish E_eco edges across the corridor's western zone (six documented in contemporary Yebouk/Ehel Adja clinical surveys; Lawsonia inermis additionally documented by Thouzery 1997 in the Adrar traditional pharmacopeia). Pre-3000 BCE origin confidence: Untested (Axiom 5; see Prediction 11); participation confidence: Moderate.

Summary of Findings

Claim	Status	Primary basis
Papyri show inversion (oldest most rational)	Confirmed	Table 1 (chronological corpus)

Claim	Status	Primary basis
Corridor botanical network (E_eco) consistent with Egypt	Confirmed	Tables 2–4 (the complete corridor botanical suite, classified by evidentiary tier (see Tables 2–4 and Section 6 Statistical Summary))
Seven plants in Mauritanian pharmacopeia AND Egyptian medicine (six documented in contemporary Yebouk/Ehel Adja clinical surveys; Lawsonia inermis additionally in Thouzery 1997 Adrar ethnopharmacology)	Confirmed (contemporary)	Yebouk 2026; Ehel Adja 2025; Hammiche 2006; Thouzery 1997 (Lawsonia inermis)
Doum palm distribution traces corridor Mauritania to Egypt	Confirmed	Adewale 2024; Orwa et al. 2009
Corridor plants pre-date the papyri archaeobotanically	Confirmed	Castor 4000 BCE; colocynth 3800 BCE; senna 3150 BCE
Richat zone as pre-3000 BCE knowledge origin	Not confirmed (Untested)	Sampling density; Axiom 5 applies
Temple of Neith at Sais — cult attestation (Naqada II, c. 3600–3350 BCE)	Confirmed	Naqada II epigraphic evidence (Wilkinson 2008; Hendrickx 1996)
Temple of Neith at Sais — medical teaching institution (predynastic)	Not confirmed	Teaching institution attested Middle–New Kingdom only; predynastic medical school is inference from cult antiquity, not direct evidence (Nunn 1996; Strouhal 2014)
Shamans → Sem priests → Priests of Sekhmet	Confirmed	Bestetti et al. 2024, Cureus
Herders as probable knowledge source	Confirmed (independent)	Haimov-Kochman et al. 2005, EJOG
Commiphora NOT native to Egypt	Confirmed	Core Model; Shen et al. 2012 (Journal of Ethnopharmacology 142(2): 319–330); genus not native to Egypt

Table S2: Summary of Findings. This table separates what the paper claims from what it does not claim. Reviewers are directed here for a clear statement of the paper's epistemic scope.

Table S3 below makes the paper's evidentiary tiers explicit. This is a hypothesis paper: its claims are by definition speculative, grounded in available data and structured to be testable. The three evidentiary categories — Evidentially grounded, Hypothesis-consistent, and Research agenda — reflect not degrees of confidence but the nature of the evidence available for each claim. Evidentially grounded claims rest on peer-reviewed primary sources and direct measurement. Hypothesis-consistent claims are supported by available data but await the specific tests identified in Section 12. Research agenda items are observations that warrant specialist investigation before any evidentiary claim can be made. All three categories are part of the hypothesis; none is an apology for it.

Claim	**Evidence base**	**Evidentiary status**	**Falsifiable?**
Chronological inversion is real (oldest texts most rational)	Direct papyri analysis; Table 1	Evidentially grounded	Yes — Falsification #2
Heka encoding mechanism: botanical knowledge preserved inside theological language; incantations accompany botanical ingredients, not replace them	Jonckheere 1947 (four modes; CB VI zero-magic); Salt Papyrus 825 (Derchain 1964–1965); Ghalioungui 1963; London Papyrus 36/61 magical prescriptions retain botanical ingredients	Evidentially grounded	Yes — Falsification #4
7 corridor plants with pre-unification presence in Egyptian record (6 Confirmed: Ricinus, Balanites, Lawsonia, Citrullus, Senna, Hyphaene; 1 Chemically Attested: Commiphora africana, pending species-specific archaeobotanical identification), drawn from sites across the Nile Valley; pre-papyrus archaeobotany brackets Shemsu Hor	Archaeobotany (eastern nodes: High); ethnobotany (Richat: Moderate, pending Prediction 11)	Evidentially grounded (eastern nodes); Hypothesis-consistent (western terminus, pending Prediction 11)	Yes — Falsification #3; Prediction 11

Claim	Evidence base	Evidentiary status	Falsifiable?
window			
Shemsu Hor transmitted botanical knowledge to Egypt (central hypothesis)	Chronological alignment + plant distribution + pastoral source identification (Haimov-Kochman 2005); circumstantial convergence	Hypothesis-consistent	Yes — Falsification #1, #5
adr- root as Saharan Berber pastoral linguistic fossil	Burkill 1985; Hammiche 2006; Miara 2019; geographic distribution across corridor nodes	Hypothesis-consistent	Partial — requires specialist linguistic review

Table S3: Evidentiary status of claims. This paper is a hypothesis; all claims are speculative in the precise sense that they are grounded in available data and structured to be tested. Evidentially grounded claims (rows 1–2) rest on direct peer-reviewed measurement. Hypothesis-consistent claims (rows 3–5) are supported by converging circumstantial evidence and await the specific tests identified in Section 12. Falsification references are to Section 12.

4. The Knowledge Source and the Western Terminus

This paper proposes that the botanical distribution in the oldest Egyptian medical texts is structurally consistent with a model in which a pastoral population with access to the botanical resources of seven ecological zones across the corridor had access to the full pharmacopeia documented in the corridor network (E_eco). The claim is ecological continuity, not causal transmission (Axioms 1–3).

The key independent confirmation: Haimov-Kochman, Sciaky-Tamir and Hurwitz (2005, European Journal of Obstetrics and Gynecology and Reproductive Biology 123(1): 3–8) concluded: 'They employed their knowledge of plants in their surroundings obtained probably by herders of domesticated animals who noticed that when animals grazed on certain plants, they failed to reproduce.' The corridor population matches this profile: pastoral cattle-herders documented across major portions of the corridor where many of the relevant plants occur. This peer-reviewed source independently identifies the probable knowledge source as the corridor population's documented profile, without reference to the Zep Tepi Series.

Two independent bodies of more recent peer-reviewed literature corroborate this mechanism, presented newest first. Wyse, Latif, Gurusinghe, McCormick, Weston and Stephen (2022, Animals 12(19): 2709, DOI: 10.3390/ani12192709) confirm that legume forage phytoestrogens (isoflavones, coumestans) disrupt reproductive function in grazing cattle and sheep through structural mimicry of mammalian estrogen — the biochemical mechanism underlying exactly the observation Haimov-Kochman et al. propose herders made. This does not show that ancient herders identified the compound class; it shows that the observable effect — animals failing to

reproduce after grazing specific plants — is real and biochemically grounded, and one a pastoral population in daily contact with its herds would have had every opportunity to notice. Independently, ethnoveterinary fieldwork confirms that pastoralist populations generally maintain field-verified diagnostic knowledge of exactly this kind, including of reproductive disorders specifically: among South African cattle-keeping communities, reproductive disorders are documented as one of the most frequently treated disease categories in living ethnoveterinary practice (Chakale, Asong, Struwig, Mwanza and Aremu 2022, Plants 11(13): 1784, DOI: 10.3390/plants11131784; Chakale, Mwanza and Aremu 2021, Frontiers in Veterinary Science 8: 710884, DOI: 10.3389/fvets.2021.710884); and Fulani pastoralists in West Africa — within the same broad Sahelian corridor zone this paper traces — display "high levels of ethnoveterinary knowledge and good clinical diagnostic abilities" independently validated against parasitological survey data (Majekodunmi, Dongkum, Idehen, Langs and Welburn 2018, One Health 5: 46–56, DOI: 10.1016/j.onehlt.2018.03.001). None of these four sources references ancient Egypt or this hypothesis; together they show that Haimov-Kochman et al.'s single-source inference describes a mechanistically real and ethnographically common pattern of pastoralist knowledge, not a speculative aside.

This section establishes the knowledge source and traces the botanical resources available at the corridor's western terminus, before the route continues eastward toward Egypt in Section 5. The corridor itself is established in Papers I–III of the Zep Tepi Series; this paper inherits that framework and maps the knowledge trail through it. The Richat/Mauritanian zone is presented as the proposed western terminus of the botanical network — all facts documented, confidence classes stated, and the claim appropriately bounded by the methodological axioms.

The African Humid Period (AHP, c. 15,000–5,000 BP) is the ecological foundation. Geological surveys confirm freshwater deposits in the Richat zone dated 15,000–8,000 BP, documenting an ecologically connected, habitable landscape during this period. Recent climate modelling has now simulated the AHP with magnitude comparable to palaeoclimate observations, confirming that these humid periods provided vegetated corridors that allowed dispersal of species including early humans across North Africa (Armstrong, Tallavaara, Hopcroft and Valdes 2023, 'North African humid periods over the past 800,000 years,' Nature Communications 14: 5549, DOI: 10.1038/s41467-023-41219-4). Crucially, the AHP termination is now documented not as a single clean event but as a centuries-long 'climate flickering' pattern: a 620,000-year palaeoenvironmental record at decadal resolution documents 20–80 year droughts recurring every approximately 160 years across the final millennium of the Green Sahara (Trauth, M.H., Asrat, A., Fischer, M.L. et al. 2024, 'Early warning signals of the termination of the African Humid Period(s),' Nature Communications 15: 3697, DOI: 10.1038/s41467-024-47921-1). This flickering model strengthens the Highland Corridor Refugia framework: populations were not driven out in a single migration but experienced repeated partial retreats to highland refugia across multiple generations, accumulating botanical knowledge at each node across the flickering window before the final northward exodus toward the Nile. As the AHP collapsed, populations concentrated at highland refugia — the nodes of the corridor — and eventually migrated toward the Nile. The chronological timeline below documents what is known at each stage.

Node 1 — The Western Terminus: Mauritania and the Adrar Plateau (Confidence: Moderate Participation; Pre-3000 BCE Origin: Untested)

The doum palm (Hyphaene thebaica) requires less inferential support than any other plant in this paper for its ecological continuity claim: it is documented in predynastic Egyptian tombs, named in the oldest medical papyri, and its native range runs from Mauritania and Senegal across the Sahelian belt directly to Egypt and Sudan — the corridor itself, without inference or

interpolation. This is an E_eco edge, not an E_seq edge (Section 3, Axioms 1–3): the range fact establishes that a corridor-native plant reaches Egypt, but a biogeographic range, however clean, does not by itself demonstrate that the plant travelled with a specific population rather than by trade, gradual ecological spread, or independent Nile Valley discovery. It is the clearest single case in which the ecological-continuity premise requires no inference or interpolation — not the clearest demonstration of transmission itself. Yebouk et al. (2026, Journal of Ethnobiology and Ethnomedicine 22(5)) document 133 medicinal and aromatic plants in the Mauritanian traditional pharmacopeia treating 17 disease categories. Mauritania is described as having 'the most detailed and diverse knowledge on traditional plant remedies of medicinal plant use' in the region. An ethnobotanical study of the Adrar Province and the Ehel Adja Clinic in Nouakchott (2025) specifically documented seven plant species in active clinical use: Commiphora africana, Combretum glutinosum, Hibiscus sabdariffa, Acacia senegal, Tamarindus indica, Senna italica Mill., and Moringa oleifera.

Six of these seven plants documented at the Ehel Adja Clinic also appear in ancient Egyptian medicine. The most actively used medicinal plants in the Richat zone's contemporary pharmacopeia are almost entirely shared with the Egyptian medical tradition. All six represent E_eco edges. Two of the six — Senna italica and Commiphora africana — have Chemically Attested pre-unification evidence in Egypt (compound-class-level identification; species-specific confirmation pending); Moringa oleifera is attested from Old Kingdom tomb contexts (early post-unification, c. 2700–2181 BCE), placing its Egyptian arrival at or immediately after unification rather than before it. The remaining three — Hibiscus sabdariffa, Acacia senegal, and Tamarindus indica — are corridor-native species that appear in Egyptian medicine but arrive after unification, consistent with the corridor model through post-unification trade channels. Whether the pre-unification continuity reflects direct corridor transmission or parallel ecological access is not established at current evidence levels (Axioms 1, 4); both explanations remain consistent with the data.

Traditional Ecological Knowledge and Oral Transmission

The confidence class of 'Untested' for the Richat zone applies specifically to pre-3000 BCE archaeobotanical evidence, reflecting the absence of any fieldwork attempt rather than weak evidence (see Section 3). A complementary evidentiary pathway exists through Traditional Ecological Knowledge (TEK). Peer-reviewed ethnobotanical literature establishes that African traditional medicine has a rich history 'dating back to the dawn of humanity... preserved and passed down through generations via oral traditions' (Oketch-Rabah and Katerere 2025, Frontiers in Pharmacology, DOI: 10.3389/fphar.2025.1616493). Pastoral knowledge systems specifically bear evidence of practices maintained over millennia, including plant-based understanding of animal nutrition, reproduction, and health outcomes that accumulate through direct observational learning across generations (Sharifian et al. 2022, Ecology and Society 27(1); Chao, Li and Reyes-García 2025, Ambio, DOI: 10.1007/s13280-025-02131-x). The Tuareg population of the Algerian Sahara — corridor Node 2 — has an ethnobotanically documented pharmacopeia consistent with TEK maintained through oral transmission across millennia (Hammiche and Maiza 2006; Miara et al. 2019: 97 plant species treating 22 ailments among Tuareg Saharan pastoralists). The Amazigh/Berber pastoral traditions common to Mauritania and the Saharan corridor are characterised in peer-reviewed literature as representing 'ancient practice' preserving 'a holistic ecological, social, cultural and institutional phenomenon' (Fernández-Giménez et al. 2021, Mountain Research and Development, citing Auclair and Alifriqui 2012 on the Agdal institution).

Within the TEK framework accepted across ethnobotany, the contemporary Mauritanian pharmacopeia documented by Yebouk et al. (2026) and the Ehel Adja Clinic study (2025) is

consistent with representing orally transmitted knowledge of potentially millennial depth. The specific antiquity of that oral chain: Untested (see Prediction 11). The seven plants shared between the Mauritanian and Egyptian medical traditions — six documented in contemporary clinical surveys, and Lawsonia inermis in the Adrar Province ethnopharmacological record (Thouzery 1997) — are therefore consistent with both present-day ecological continuity AND ancient oral transmission — two explanations not mutually exclusive and both compatible with the corridor model. This raises the effective confidence class for the Mauritanian oral knowledge connection from 'Untested' (archaeobotanical) to 'Moderate' (TEK oral transmission framework). The upgrade to 'Moderate' reflects methodological convergence across four independent disciplines — not confirmed historical continuity, which awaits archaeobotanical confirmation (Prediction 11). It means the oral transmission hypothesis is more plausible than the archaeobotanical evidence alone would suggest, without establishing 5,000-year continuity as a demonstrated fact. The four independent lines are:

1. Documented intergenerational transmission within specialized families in the Adrar region, with 46 species and seven direct correspondences to the paper's confirmed and probable pre-unification corridor plants (Thouzery 1997, 2002);

2. An 800-year written and oral chain anchored to Ibn al-Baytar (13th century CE) through Hamidoun (Ould Hamidoun, 1952), Thouzery (1997), and Yebouk et al. (2020) — a chain now extended to 1937 through Dubié's colonial documentation of Moorish medicine (Dubié 1937) and to 1953 through the first comprehensive scientific ethnopharmacological survey of the Mauritanian pharmacopeia (Leriche 1953, 'Phytothérapie maure', Mémoires de l'IFAN 23: 267–306), both independently confirmed in the Yebouk series bibliography and in Thouzery and Ould Mohamed Vall (2011) — documenting unbroken continuity of specific medicinal uses in the Adrar zone;

3. A documented pastoral transmission mechanism — generational tracking of Commiphora leaf cycles as grazing guides — providing a concrete accumulation and transfer mechanism (Le Houerou 1980);

4. aDNA evidence of ancient population continuity from Taforalt (Morocco, 15,000 BP) through Takarkori (Libya, 7,000 BP; Salem et al. 2025), whose modern echoes split geographically: southward into Fulani populations (D'Atanasio et al. 2023), and within the Maghreb/western Sahara into Saharawi and other Berber-speaking populations (Serra-Vidal et al. 2019) — the same broad population as the Mauritanian Bidhan/Haratine communities carrying the Adrar TEK. This establishes the deep antiquity of a related Saharan lineage and identifies the geographically relevant modern branch, but does not itself establish direct genetic continuity with the specific population documented here — the weakest of the four lines below, included for completeness rather than as independent confirmation. The specific question — whether oral knowledge transmission across 5,000 years is plausible in this cultural context — is directly addressed by two independent bodies of peer-reviewed evidence.

First, geomythological research has demonstrated that oral traditions in pastoral and indigenous contexts can maintain factual accuracy across 7,000–12,000 years when supported by kin-based transmission structures: Nunn and Reid (2016, 'Aboriginal Memories of Inundation of the Australian Coast Dating from More than 7000 Years Ago,' Australian Geographer 47(1): 11–47, DOI: 10.1080/00049182.2015.1077539) verified 21 Aboriginal Australian coastal stories against sea-floor bathymetry, dating them to 7,250–13,070 cal yr BP; Hamacher, Nunn et al.

(2023, ‘The archaeology of orality: Dating Tasmanian Aboriginal oral traditions to the Late Pleistocene,’ Journal of Archaeological Science, DOI: 10.1016/j.jas.2023.105819) further confirmed Palawa stories at 12,000+ years using two independent verification methods (sea-floor topography and stellar precession), demonstrating transmission across 470+ successive generations. The key enabling mechanism in both cases — kin-based responsibility to transmit accurately — is precisely the structure documented in the Adrar region by Thouzery (1997, 2002): specialized family-based transmission, not casual oral tradition. The methodology of treating archaeological questions through oral tradition evidence has itself been formalised in the field’s authoritative reference: the Oxford Handbook of Indigenous Oral Traditions and Archaeology (Bruchac et al., Oxford Academic, September 2024, DOI: 10.1093/oxfordhb/9780197557686.001.0001) positions archaeology as increasingly engaging with oral traditions as records of history transmitted across generations via practices of memory, ecological knowledge, and situated learning.

Directly relevant to the Amazigh pharmacopeia specifically, Applequist (2025, ‘Persistence of Use Among Amazigh People of Medicinal Plants Documented by Ibn al-Baytar,’ Plants 14(3): 342, DOI: 10.3390/plants14030342) independently validates the Amazigh oral pharmacopeia’s stability, finding that 60.9% of Ibn al-Baytar’s Berber-named plants remain in use, with 78.6% retaining homologous common names, in a population whose traditional knowledge ‘was largely transmitted orally, with little access to medieval literature’ — explicitly ruling out literary transmission as the source of continuity. Five-thousand-year oral continuity is documented as achievable in analogous traditions with comparable structural transmission mechanisms; this establishes that the claim is plausible for the Adrar pastoral tradition, not that it has been demonstrated for it specifically. One inferential assumption underlies this upgrade and should be stated explicitly: that documented cultural and population continuity implies knowledge continuity — that the same families transmitting medicine in the Adrar today carry knowledge whose deep structure derives from the same pastoral tradition documented archaeologically. This assumption is itself supported by the TEK literature cited above (Nunn and Reid 2016; Hamacher et al. 2023; Applequist 2025), which demonstrates that structured kin-based transmission systems can maintain factual accuracy across timescales far exceeding the 5,000 years proposed here. The assumption is nonetheless an assumption, not a demonstrated fact for this specific tradition; its validity is precisely what Prediction 11 is designed to test. A methodological note on the TEK analogy: the Australian coastal flooding evidence (Nunn and Reid 2016; Hamacher et al. 2023) involves geographic knowledge verifiable against fixed bathymetric data, whereas botanical knowledge is more fluid and harder to anchor across generations without textual records. The relevant parallel is not the type of knowledge being transmitted but the transmission mechanism: structured kin-based oral practice with consistent daily application context. A pastoral family that transmits plant knowledge through daily herding, healing, and food preparation has the same mechanism — structured, repeated, socially enforced, application-grounded — as an Aboriginal community transmitting coastal geography through ceremonial narrative. It is the fidelity of the mechanism that the TEK literature documents, not the equivalence of the content type. Three further precedents strengthen this analogical case.

Second, Pinotti et al. (2025, ‘Picuris Pueblo oral history and genomics reveal continuity in US Southwest,’ Nature 642: 125–132, DOI: 10.1038/s41586-025-08791-9) used ancient and modern genomes to confirm the Picuris Pueblo’s oral tradition of ancestral connection to the Ancestral Puebloan population of Chaco Canyon, a claim the community’s oral history had maintained for roughly a millennium. This is methodologically closer to the present argument than the coastal-flooding studies: it verifies population continuity and ancestral connection — the same category of claim this paper's genetic evidence circumstantially supports for the

Mauritanian pharmacopeia via the two-branch pattern documented in Section 9 — and does so through genetic rather than geological corroboration.

Third, the Vedic oral tradition demonstrates that entire integrated knowledge systems, not isolated facts, can survive high-fidelity oral transmission over comparable timescales: the Rigveda has been transmitted with documented phonetic precision since approximately 1500–1200 BCE through formal mnemonic recitation techniques maintained within specialist families — a structure directly analogous to the specialist family-based transmission Thouzery (1997, 2002) documents in the Adrar region. The botanical knowledge the corridor population carried was not abstract — it was enacted daily in wound care, water treatment, reproductive health, and animal husbandry. That daily enactment is precisely the application-grounded context that the TEK literature identifies as the primary stabilising mechanism for oral transmission fidelity. A further objection — that botanical knowledge is susceptible to ecological substitution over time, with a functionally equivalent plant replacing the original without the tradition recognising the change — does not apply here: the corridor evidence documents Commiphora africana specifically at every node from Mauritania through the Sahel to Sudan — the corridor's easternmost node before Egypt itself — under variants of the same adr- name, not a pattern of different plants carrying the same name at different points along the route. Substitution would predict name-plant dissociation across nodes; the evidence shows the opposite within the corridor. The name does not itself continue into ancient Egyptian (Section 7), so this argument addresses substitution risk along the corridor, not the separate question of the transmission step into Egypt.

Fourth, structured griot oral transmission provides an archaeologically verified case of the same fidelity, in a living hereditary tradition of the same general type as the Mauritanian iggawin. In 2024, Canós-Donnay's excavation of Kansala, the legendary capital of the Kaabu kingdom (Guinea-Bissau), reported preliminary physical evidence of fortifications, trade infrastructure, and a gunpowder house whose destruction is preserved in griot oral history — findings so far presented in the popular-scientific and news press rather than in a peer-reviewed report (Archaeology, May/June 2024; NPR, 27 April 2025). This does not establish 5,000-year continuity for the botanical knowledge proposed here; it establishes that the same structured, hereditary, application-grounded oral transmission mechanism this section identifies as the stabilising factor — and that Thouzery (1997, 2002) documents for the Adrar pharmacopeia specifically — can preserve historically accurate information that archaeology later confirms.

Hibiscus sabdariffa: Corridor-Native Post-Unification Arrival

Hibiscus sabdariffa (karkadeh, roselle) is documented in the Ebers Papyrus (c. 1550 BCE) as a remedy for coughs and is known in Egypt as Karkadeh, the 'Tea of the Pharaohs.' It was domesticated in Sudan — a mid-corridor node — at approximately 4000 BCE (Murdock 1959; Fuller and Hildebrand 2013). Its corridor origin is not in doubt; its first confirmed physical presence in Egypt is the Ebers Papyrus (1550 BCE), placing it firmly in the post-unification period. Egypt's expanded trade networks after unification provide the most parsimonious arrival mechanism. Hibiscus is therefore treated in this paper as a corridor-native post-unification arrival: its presence in Egyptian medicine is consistent with the corridor model, but it cannot serve as pre-unification archaeobotanical evidence. It is documented in the Mauritanian pharmacopeia at the Ehel Adja Clinic and in the Adrar pharmacopeia (Thouzery 1997). Contemporary validation: confirmed antihypertensive, antimicrobial, anti-inflammatory, diuretic, and antioxidant properties (Da-Costa-Rocha et al. 2014, 'Hibiscus sabdariffa L. — A Phytochemical and Pharmacological Review,' Food Chemistry 165: 424–443, DOI: 10.1016/j.foodchem.2014.05.002; Almajid, F. et al. 2023, 'Exploring the Health Benefits and

Therapeutic Potential of Roselle (Hibiscus sabdariffa) in Human Studies: A Comprehensive Review,' Cureus 15(11): e49309, DOI: 10.7759/cureus.49309); currently used in clinical trials for hypertension management globally.

Doum Palm (Hyphaene thebaica) — The Corridor in a Distribution Map

The doum palm is documented in ancient Egyptian papyri and tomb paintings and its fruits have been found in pharaonic tombs. Its geographic range is the most striking single piece of evidence for the Richat connection: 'H. thebaica grows in the west from Mauritania and Senegal and east to Egypt, Kenya, and Tanzania' (Adewale 2024, Journal of Food Biochemistry). The World Agroforestry Centre's species reference database confirms this distribution in detail, listing the doum palm's native range as extending from Mauritania and Senegal across the Sahel to Egypt and Sudan (Orwa et al. 2009) — the Sahelian belt the corridor traverses. The doum palm requires less inferential support than any other plant in this paper. Its geographic distribution is non-inferential: Nunn (1996, Ancient Egyptian Medicine, Table 8.1, p. 155) lists Hyphaene thebaica (Egyptian names: mama, ququ) with Predynastic first recorded use. The plant's native range is consistent with the corridor route. Contemporary validation: confirmed antibacterial activity against Staphylococcus aureus and Pseudomonas aeruginosa; broad-spectrum pharmacological profile (Adewale 2024, Journal of Food Biochemistry).

Commiphora — The Bridge Plant: Species, Documentation, and Transmission

Myrrh (Commiphora) is documented in the Ebers Papyrus for diarrhea, headaches, gum ailments, toothache, and backache, and was heavily used in Egyptian embalming. The critical detail: Commiphora africana is classified in the Sahara–Sahel–Nile Botanical Network framework as 'NOT native to Egypt' but 'Sahel-wide.' Egypt had to obtain Commiphora from the corridor zone. Its presence in the Ebers Papyrus is consistent with arrival via the corridor network. It is documented in the Mauritanian pharmacopeia at the Ehel Adja Clinic. Its chemistry has been characterised in detail: a doctoral study of Commiphora africana resin sourced specifically from Mauritania documents its chemical and physico-chemical composition (Abdellahi 2013); the volatile compounds and biological effects of Commiphora africana incense have since been confirmed pharmacologically (Eltigani et al. 2025); and the sesquiterpenoid, triterpene, and steroid chemistry of the wider genus is documented in the closely related species Commiphora myrrha (Unterholzner et al. 2024).

Species Presence and Habitat History in the Adrar Zone

Commiphora africana is confirmed in the Adrar region of Mauritania — the region containing the Richat Structure — through GBIF occurrence records, iNaturalist observations, peer-reviewed ethnobotanical surveys, and the earliest formal scientific botanical surveys of the region. The naturalist Théodore Monod — who first explored the Richat Structure scientifically on 7 July 1934 and made it the focus of a dedicated geological excursion during the XIXème Congrès Géologique International in October 1952 (Monod 1956, 'Notes sur l'excursion D10 (Adrar mauritanien)', Bulletin de l'IFAN, tome XVIII, sér. A, n°2: 633–651) — simultaneously published the first comprehensive botanical inventory of the Adrar Plateau in the same year, documenting 230 vascular plant species across the same plateau containing the Richat Structure (Monod 1952, 'Notes botaniques sur l'Adrar (Sahara occidental)', Bulletin de l'IFAN 14A: 405–449; continued in Monod 1954, Bulletin de l'IFAN 16A: 1–48). Monod was therefore the founding scientific authority on both the Richat's geology and the Adrar's botanical inventory. These surveys constitute the earliest formal record of the Adrar's plant diversity — the same region where Commiphora africana and Balanites aegyptiaca are confirmed in every subsequent ethnobotanical survey, including Yebouk et al. (2020) who surveyed Ouadane directly, building

on the floristic foundation Monod established. The definitive Mauritanian flora catalogue (Lebrun 1998) subsequently confirmed both species in the Adrar zone through peer-reviewed synthesis of all available herbarium and literature records, with Commiphora africana cited from Monod's 1954 collections between Tifrirt and Aouelloul and Balanites aegyptiaca confirmed at Atar and the Amojjar Pass on the Adrar Plateau. Monod's own field survey provides an even more precise, site-internal confirmation: in a 1974 dispersal-biology study based on 32 vegetation transects walked across the Adrar between 23 December 1973 and 16 January 1974, he recorded three individual specimens of Balanites aegyptiaca growing directly inside the Richat Structure itself, at Graret el-Guelb, alongside Acacia ehrenbergiana and Maerua crassifolia — the same Maerua species that survives at the central dome today (Monod, T. 1974, 'Spectre de modes de dissémination dans l'Adrar mauritanien (Sahara occidental)', Candollea 29: 401–425, relevé n° 17). A 1988 French-language biogeographic study of the Tagant massif (which borders the Adrar) identifies Commiphora africana as a diagnostic marker for the Sahelian vegetation zone and confirms that a Holocene wet period (9,630 ± 150 BP) created 'tamourt' (rocky shelters) providing refuges for species with 'more meridional biogeographical distribution' (Barry et al. 1988, 'Note IX: le Tagant', Ecologia Mediterranea 14: 155–183). A parallel peer-reviewed phytosociological study of the Adrar Plateau itself — the massif containing the Richat Structure — documents the Acacio-Aristidion community as characteristic of the Adrar's southern Saharan and Sahelian border zone, a community whose diagnostic species include Commiphora africana and Balanites aegyptiaca (Barry, J.-P., Jaouen, X., Musso, J. and Riser, J. 1987, 'Le problème des divisions bioclimatiques et floristiques au Sahara. Note VI: entre Sahel et Sahara: l'Adrar mauritanien. Approches biogéographique et géomorphologique', Ecologia Mediterranea 13(1–2): 131–181). This same study describes the Adrar as 'une passerelle entre toutes les flores' — a bridge between all floras — independently deploying corridor language for the same zone the present paper identifies as its western terminus.

During the African Humid Period — the corridor's ecological window — the Sahelian vegetation zone extended hundreds of kilometres northward. Commiphora africana would have been a native component of the Adrar Plateau flora during the pastoral occupation window (6,000–3,000 BCE), with the water-retaining depressions and wadis of the Richat Structure providing suitable habitat. Commiphora africana requires 300–800 mm annual rainfall (Le Houerou 1980, 'Commiphora africana, browse tree of the Sahel'); the Adrar region receives approximately 11 mm today, well below this threshold. The plant's current absence from the central depression reflects contemporary hyper-aridity, not past distribution. Contemporary field documentation confirms this: the Richat Structure's central dome is today almost entirely denuded of vegetation — only a small grove of Maerua crassifolia, known in Hassaniya as atil, survives at the eastern edge of the central massif. This is not a corridor plant. The corridor species — Commiphora africana (âdres), Balanites aegyptiaca (teïchot), Acacia spp. — characteristically inhabit wadi beds and alluvial flats, and are confirmed throughout the broader Adrar zone in every botanical survey from Monod (1952, 1954) onward. The Richat Structure's external ring depression contains the wadi systems of Akerdil and Bamouéré, whose AHP-era alluvial deposits confirm seasonal water presence during the pastoral occupation window (Sao, O. et al., 'Paleo-environmental study of Quaternary sediments of the Guelb er Richat', XIXth INQUA Congress documentation, AMS dates 7,730–15,000 BP corresponding to the African Humid Period). The claim is not that these plants grow at the Richat today, but that they inhabited its active wadi systems during the AHP and remain documented in the broader Adrar pastoral territory. The physical evidence of Commiphora's presence during the pastoral occupation window: Untested (see Prediction 11). (The theological encoding of Commiphora as Ra's tears, and its appearance across the rational-to-ritual spectrum of the medical corpus, is discussed in Section 2.)

The earliest formal botanical documentation of the Adrar's plant diversity predates any ethnopharmacological survey by four decades. Naegèle (1958, 'Note sur quelques plantes récoltés à Chinguetti (Adrar Tmar)', Bulletin de l'IFAN sér. A, 20(2): 293–305) subsequently documented 26 species specifically at Chinguetti — the ancient Adrar city approximately 130 km southwest of the Richat — with Hassaniya vernacular names, providing the first formal record of local nomenclature for plants in this specific pastoral territory. Adam (1962, 'Inventaire des plantes signalées en Mauritanie', Journal d'Agriculture Tropicale et de Botanique Appliquée IX(3–6): 85–200) then compiled the first comprehensive all-Mauritania flora inventory. Together, Monod (1952, 1954), Naegèle (1958), and Adam (1962) establish the formal botanical baseline for the Adrar zone. The definitive critical catalogue synthesising all historical and modern botanical records for the region — Lebrun, J.-P. (1998), Catalogue des plantes vasculaires de la Mauritanie et du Sahara occidental, Boissiera 55, Conservatoire et Jardin botaniques de Genève, 322 pp. (DOI: 10.5169/seals-895416) — provides peer-reviewed Adrar-zone confirmation for all six major corridor plants discussed in this paper. Senna italica is documented at Atar and Hamdoun; a colonial-era herbarium specimen (Schmitt in Chevalier 28517) records it as 'en abondance dans les oueds de l'Adrar' — in abundance in the wadis of the Adrar. Citrullus colocynthis is confirmed at Atar and in the northern and north-western Adrar (Schmitt in Chevalier 28509). Two further corridor plants — Lawsonia inermis (henna) and Ricinus communis (castor bean) — are documented specifically at Ouadane by Monod's 1977 collections (Lebrun 1998: 6832, 9953), placing these species within approximately 40 km of the Richat Structure's centre. This constitutes the closest documented botanical location to the Richat for any corridor plant confirmed in the peer-reviewed literature.

Lebrun (1998) additionally records that Monod's 1952 botanical survey included physical specimen collection within the Richat Structure itself — specifically from the western cliff of oued Bamouéré (cited as oued Bamwéré, Richat), the external ring wadi of the structure — documenting Rumex vesicarius, Andrachne telephioides, and Astragalus eremophilus at this exact location. These are not corridor plants; they are drought-adapted species characteristic of current hyper-arid conditions. Their documentation confirms that systematic botanical survey was conducted within the Richat's own wadi system, and that the same botanist who established the Adrar's corridor-plant record was simultaneously conducting surveys within the Richat's internal drainage. The earliest systematic ethnopharmacological documentation of the Adrar pharmacopeia was conducted by Thouzery (1997), whose fieldwork specifically in the Adrar region produced a species list documenting the traditional medicinal use of 46 plant species among Moorish populations in the area containing the Richat Structure (Thouzery, M. 1998, Phytothérapie Maure: étude ethnopharmacologique dans l'Adrar, Mémoire d'ethnopharmacologie appliquée, Université de Metz). Cross-referencing Thouzery's Adrar species list against this paper's confirmed and chemically attested pre-unification corridor plants reveals seven named correspondences: Commiphora africana (Hassania name: adress), Balanites aegyptiaca (tesot), Citrullus colocynthis, Senna italica, Cassia senna, Ricinus communis, and Lawsonia inermis. This is not the same list as the seven confirmed and chemically attested pre-unification corridor taxa tallied in Section 6: it names Senna's Mauritanian and Egyptian species (Senna italica and Cassia senna) separately rather than as the single combined corridor thread used elsewhere in this paper, and it does not include Hyphaene thebaica. Six of the seven confirmed and chemically attested pre-unification corridor plants tracked elsewhere in this paper as corridor botanical threads — all except the doum palm — were independently documented in the Adrar traditional pharmacopeia twenty-two years before the Yebouk series began. Tamarindus indica, Acacia senegal, and Hibiscus sabdariffa — corridor-native species also present in the Adrar pharmacopeia and in Egyptian medicine — arrive in Egypt after unification and are noted separately as post-unification corridor arrivals. The Hassania indigenous name for Commiphora africana — adress — signals deep cultural

familiarity with this plant in the Adrar zone where the Richat sits (see Section 7 for the adr- name trail across the corridor).

Ethnopharmacological Documentation: The Yebouk Adrar Survey

The Yebouk et al. (2020) Adrar Province survey, which specifically included the town of Ouadane — the settlement nearest to the Richat Structure — identifies Balanites aegyptiaca as the most cited medicinal plant in the entire province, with 278 use reports and complete informant consensus across three pathological groups. Balanites aegyptiaca is the same plant documented archaeobotanically at Takarkori (Node 3) 7,000 years ago. Its emergence as the top-priority medicinal species in Ouadane creates a direct documented botanical thread between the corridor's most securely-dated archaeological node and the proposed western terminus zone. The presence of Balanites aegyptiaca as naturally growing populations in the hyper-arid zones of Mauritania — at rainfall levels below 50 mm annually, among the lowest in which any tree survives — is independently confirmed by a peer-reviewed phytochemical study that sampled 30 trees from five natural populations across Mauritanian arid and hyper-arid zones, including sites at the northern distributional limit of the species in Mauritania (Mint Abdelaziz, S. et al. 2020, 'Phytochemicals, Antioxidant Activity and Ethnobotanical Uses of Balanites aegyptiaca (L.) Del. Fruits from the Arid Zone of Mauritania', Plants 9(3): 401, DOI: 10.3390/plants9030401). The Hassaniya name recorded in that study — Toogga/teïchot — is the same term used in the Adrar ethnobotanical record, confirming cultural continuity of the species' identification across the Mauritanian pastoral tradition. Commiphora africana is documented as polyvalent across six clinical conditions from three pathological groups in the same study, consistent with its status as a medicinal cornerstone across the entire corridor.

The Written and Oral Knowledge Chain

The Yebouk et al. (2020) study notes that six of the 68 Adrar Province medicinal species are also cited in Ibn al-Baytar's thirteenth-century CE compendium of simple medicaments — the most authoritative Islamic medical encyclopedia of the medieval period. This creates an 800-year documented knowledge chain for elements of the Adrar pharmacopeia: from Ibn al-Baytar (13th century CE) — its knowledge preserved within a living Greco-Arabic written medical tradition in Mauritania traced back to Hippocrates, Galen, and Avicenna (Graz and Barras 2015), and transmitted via the oldest known Arabic medical treatise of the Moorish tradition, the 'Al-Umda' medical poem of Awfa b. Babakkar (composed pre-1850; French translation: Dubié 1943) — through Dubié's first colonial French documentation of Moorish medicine (Dubié 1937) and Leriche's systematic pharmacopeia survey (Leriche 1953), through Hamidoun (Ould Hamidoun, 1952) and Thouzery (1997), to the Yebouk series (2020–2023). The paper itself observes that traditional medicine knowledge 'is particularly important within particular families which have owned, practiced and transmitted it for several generations' — confirming structured, family-based intergenerational transmission rather than casual oral tradition. The IRD publication based on Thouzery's work similarly notes 'une médecine originale transmise de génération en génération au sein de familles spécialisées dans cette activité' — an original medicine transmitted from generation to generation within families specialised in this activity (Thouzery 2002, in IRD Éditions, Des sources du savoir aux médicaments du futur). This structure of family-based specialist transmission is independently documented by Graz and Barras (2015) in their peer-reviewed study of the Maqari family — one of three recognised lineages of traditional Mauritanian practitioners — whose written Arabic medical treatise synthesises the pharmacopeia of the western Sahara within a Hippocratic-Galenic framework. Graz and Barras describe explicitly 'une continuité extraordinairement longue, de près de 2500 ans' — an extraordinarily long continuity of nearly 2,500 years from the first Hippocratic texts to

the contemporary Mauritanian clinic. The same article confirms that the parallel Mauritanian tradition, the ‘Al-Umda’ medical poem of Awfa b. Babakkar (pre-1850), likewise cites Avicenna, Galen, and Hippocrates directly, establishing a documented written chain from ancient Mediterranean medicine into the Moorish tradition. This is consistent with the Avicennan Canon’s own explicit incorporation of medicine ‘unknown to the Greeks’ (Masic 2012), which on this hypothesis included plant knowledge from African pastoral sources transmitted via Arabian trade networks. Together, these sources document the Mauritanian pharmacopeia as the western terminus of a written and oral knowledge tradition whose earliest documented anchor point is the medieval Islamic reception of ancient Greek medicine, and whose contemporary expression continues the same family-specialist transmission structure proposed for its prehistoric predecessor.

Archaeological Evidence of Pastoral Occupation

The Adrar Plateau's pastoral occupation is archaeologically documented. The Agrour Amogjar site, located at 690 metres elevation on the Adrar Plateau within the Richat zone, houses Neolithic rock paintings spanning eight stylistic groups including a pastoral period phase. The stylistic chronology follows Mauny (1954) and is confirmed by Vernet (2006, in Hic sunt leones: mélanges sahariens en l'honneur d'Alfred Muzzolini, Cahiers de l'AARS 10: 199–206), who documented the site directly; Mauny's naturalist-to-pastoral period is dated to 5,000–2,000 BCE on stylistic grounds, placing the pastoral occupation of the Richat zone well within the proposed Shemsu Hor integration window. The Adrar Plateau features stone circles including the documented Atar Stone Circle, and the Adrar Region has evidence of cattle pastoralism continuing as late as 1,000 BCE (Mauny 1954; Vernet 1993). These are not inferences from ecological continuity but documented archaeological occupation of the specific landscape containing the Richat Structure during the proposed pastoral window. The under-excavation of this zone reflects modern access constraints, not absence of human presence (Axiom 5; introduced in Paper I of this Series).

The Adrar Province Survey: Scope and Scale

An ethnobotanical study of the Adrar Province specifically — the administrative zone containing the Richat Structure — documents 68 plant species across 27 botanical families used in traditional medicine in this zone, treating 50 health conditions grouped in 14 pathological categories (Yebouk et al. 2020, Journal of Ethnopharmacology 239:111927, Adrar Province fieldwork). This study is geographically more specific than the broader Mauritanian survey (Yebouk et al. 2026, covering all of Mauritania). The most-used plant families are Fabaceae (14 species) and Poaceae, with primary concentrations on gastrointestinal and dermatological conditions — the same clinical emphasis documented in the oldest Egyptian medical papyri.

The Transmission Mechanism

The link between pastoral movement and Commiphora knowledge is ethnographically documented. Herdsmen of the northern Sahel follow the seasonal leaf cycles of Commiphora africana as a grazing guide: 'Herdsmen of the northern Sahel follow the rainfall patterns and the C. africana trees as they come into leaf, continually finding new areas for their animals to browse' (Le Houerou 1980, 'Commiphora africana, browse tree of the Sahel,' in Browse in Africa: the current state of knowledge, Nairobi). This pastoral tracking behaviour provides a direct mechanism for the accumulation and transmission of Commiphora's medicinal properties along the Sahelian pastoral network. The plant's seasonal leaf cycle gave herders repeated, generation-by-generation exposure to its resinous properties — its antimicrobial, antiseptic, and wound-healing applications directly observable from animal grazing behaviour and wound

outcomes. This is the transmission mechanism the corridor model requires. For the Richat zone's AHP deposits, tumuli, stone fortresses, and rock art, see Paper I (Levy 2026a); for the Salem et al. 2025 genetic link to Takarkori, see Paper II (Levy 2026b).

Acacia senegal: Post-Unification Corridor Arrival

Acacia senegal is native to the Sahel corridor zone and is documented in the Mauritanian pharmacopeia and in Egyptian medicine (Ebers Papyrus, Kahun Papyrus contraceptive prescriptions; the gum's phytochemistry and traditional medicinal uses are reviewed by Ashour et al. 2022, Molecules 27(4): 1171). Its earliest confirmed physical presence in Egypt is Old Kingdom, c. 2650 BCE — post-unification. It cannot serve as pre-unification archaeobotanical evidence, but its corridor origin and Egyptian medical attestation are consistent with the broader corridor transmission model operating through post-unification trade channels. Acacia gum, when fermented, releases lactic acid — a spermicide still used in modern contraceptive formulations (Riddle 1992, Harvard University Press; Thomas et al. 2020, Contraception: X 2: 100031). The lactic acid mechanism documented in Egyptian acacia-gum contraceptive recipes is now the active ingredient of Phexxi, an FDA-approved spermicide licensed in the United States in May 2020 (FDA approval NDA 208088) — the exact pharmacological pathway the Kahun Papyrus exploited circa 1825 BCE.

Henna (Lawsonia inermis)

Henna (Lawsonia inermis) is documented in the Ebers Papyrus for use as an astringent, to stop diarrhea, and to close open wounds (Aboelsoud 2010, Journal of Medicinal Plants Research 4(2): 082–086). It is native to 'northern and eastern Africa, Asia and northern Australia, in semi-arid zones and tropical areas' (Migahid 1978, Flora of Saudi Arabia; distribution documented across North Africa and the Sahel), making it a North African corridor-zone native. Also known as the 'Egyptian privet,' it was cultivated in Egypt from the Middle Kingdom. No specific contemporary clinical documentation has been found in the Yebouk or Ehel Adja surveys; however, Lawsonia inermis appears in Thouzery's (1997) Adrar Province ethnopharmacological species list among the 46 plant species documented in traditional use in the zone containing the Richat Structure. This constitutes historical Mauritanian corridor-zone documentation. Its North African distribution further establishes an E_eco edge. Confidence: Moderate.

5. The Corridor Route: From the Sahara to the Nile

This section continues the knowledge-gathering timeline from the western terminus (Section 4) through the remaining corridor nodes to the Egyptian endpoint, in chronological sequence. Each node is assessed for what botanical knowledge was available, what is documented, and how it is consistent with the knowledge accumulation model.

Node 2 — Tassili n'Ajjer (Confidence: High)

Hammiche, V. and Maiza, K. (2006). Journal of Ethnopharmacology 105(3): 358–367. DOI: 10.1016/j.jep.2005.11.028. Documented species with correspondence in Egyptian medicine: Acacia albida Del., Acacia seyal Del. (same genus as Kahun Papyrus contraceptive); Artemisia campestris L. (documented for post-partum care; the Ramesseum Papyri focus on post-partum recovery — same plant, same application domain); Artemisia judaica L. (documented for helminthiases); Balanites aegyptiaca Del. (documented for digestive ailments). The Tassili rock art spans approximately 12,000 years (Muzzolini 2001); the Round Heads period (c. 9,000–

7,000 BCE) includes anthropomorphic figures widely interpreted as ritual or religious in character — dancing and apparent worship postures (Soukopova 2011, 2012).

Reverse-Pharmacology Precedent: Artemisia

The 2015 Nobel Prize in Physiology or Medicine was awarded jointly to Tu Youyou 'for her discoveries concerning a novel therapy against Malaria' derived from Artemisia annua, and to William C. Campbell and Satoshi Ōmura for ivermectin (Nobel Prize Committee, 5 October 2015). This case is a direct illustration of reverse pharmacology in practice. Tu Youyou's discovery did not come from a laboratory screen of synthesized compounds — it came from systematic consultation of ancient Chinese medical texts, specifically the 4th-century compendium of Ge Hong, where the antifebrile properties of sweet wormwood had been recorded 1,700 years earlier (Tu, Nobel Lecture, Karolinska Institute, 7 December 2015: 'Discovery of Artemisinin: A Gift from Traditional Chinese Medicine to the World'). The Nobel Committee's press release states explicitly: "Tu revisited the ancient literature and discovered clues that guided her in her quest to successfully extract the active component from Artemisia annua" (Nobel Prize Committee 2015). This is the precise model this paper proposes for the Egyptian medical corpus: that ancient botanical knowledge, encoded in texts compiled from earlier oral sources, contains genuine pharmacological intelligence recoverable by modern analysis. The antimalarial activity of artemisinin from Artemisia annua was first published in English by the Qinghaosu Antimalaria Coordinating Research Group (1979, 'Antimalarial studies on qinghaosu,' Chinese Medical Journal 92: 811–816) and subsequently reviewed by Klayman (1985, 'Qinghaosu (Artemisinin): An Antimalarial Drug from China,' Science 228(4703): 1049–1055). Artemisinin-based combination therapies are now standard treatment worldwide for P. falciparum malaria. The Artemisia genus documented at Tassili for post-partum care and antiparasitic use is the same genus whose antiparasitic activity is Nobel Prize-confirmed. The Egyptian Ebers Papyrus documents Artemisia in antiparasitic and gynaecological applications (Manniche 1989). The corridor botanical knowledge and the Egyptian corpus share not just the plant but the application domain — antiparasitic and reproductive health — in a pattern consistent with a single knowledge tradition encoding genuine biological activity that modern pharmacology has independently confirmed. Both Nobel Prize cases in this paper illustrate the same methodological point: ancient botanical pharmacopoeias — whether Egyptian or Chinese — can encode pharmacologically active compounds that withstand modern scientific scrutiny. This is a precedent for the method of reverse pharmacology, not a validation of this paper's corridor-transmission hypothesis specifically. The 2015 Prize is best read as validating reverse pharmacology as a method — taking a specific ancient textual detail seriously as a lead for modern investigation, rather than as decorative color. That precedent supports treating the Egyptian medical corpus as a plausible repository of genuine pharmacological knowledge. It does not, by itself, establish where that knowledge came from; the corridor-transmission argument rests on the archaeobotanical, genetic, and linguistic evidence presented elsewhere in this paper, not on the Nobel precedent.

Contemporary Validation: Balanites aegyptiaca

Balanites aegyptiaca is the Adrar Province's most-cited medicinal plant (Yebouk et al. 2020; see Section 4 for the full use-report figures). Its comprehensive pharmacological profile — antioxidant, antimicrobial, anti-inflammatory, antiplasmodial, and wound-healing — is documented in the peer-reviewed literature (Thakkar et al. 2025; Sharma and Sharma 2026; Tsila et al. 2025). The same Takarkori link already established (Section 4; di Lernia et al. 2024) applies here too. Its multi-domain applications in Egyptian medicine, perfumery, soap-making, and pest control are discussed in Section 9.

Node 3 — Takarkori, Tadrart Acacus (Confidence: High — Archaeobotanical)

di Lernia et al. (2024). DOI: 10.1371/journal.pone.0310739. Balanites aegyptiaca drupes are 'among the most common archaeobotanical remains' at the Holocene pastoral site. This is an E_arch edge: the plant is physically in the preserved botanical record of the corridor site, not merely documented in ethnobotanical surveys. The Tuareg Kel Tadrart still use the same plant medicinally — continuous from the Holocene pastoral period to the present. Three independent documentation points on a single plant: Tassili pharmacopeia (Node 2), Takarkori archaeobotanical record (Node 3), Egyptian traditional medicine (destination).

Nodes 4–6 — Messak Settafet, Gilf Kebir, and Nabta Playa

These nodes do not currently yield specific archaeobotanical medical evidence (E_arch absent; E_eco only). Messak Settafet (Libya, Node 4): therianthrope rock art tradition consistent with shamanic healing iconography globally. Gilf Kebir/Wadi Sura (Egypt, Node 5): Cave of Beasts hybrid figures; no specific medical plant evidence published. Rock art documentation at Jebel Uweinat and Gilf Kebir confirms that all preceding hunter-gatherer cultures in this zone were replaced by a homogenous culture of cattle pastoralists (Zboray et al. 2025, in Förster et al. eds., Current Research in the Rock Art of the Eastern Sahara, IBAES 27, GHP London), corroborating the pastoral population profile at this corridor node. Nabta Playa (Egypt, Node 6): cattle-herding community with sub-Saharan African osteological origins, consistent with the herder profile Haimov-Kochman et al. (2005) identify as the probable knowledge source; no specific medical plant evidence published. Rock art from the First Cataract area — the corridor gateway between the eastern nodes and the Egyptian destination — provides independent evidence of cultural contact during the fourth millennium BCE integration window (Brémont and Vanhulle 2025, in Förster et al. eds., Current Research in the Rock Art of the Eastern Sahara, IBAES 27, GHP London), consistent with the pastoral population's documented approach to Hierakonpolis across this period.

Node 7 — Hierakonpolis: The Egyptian Integration Point (Confidence: High)

Predynastic Fracture Healing

The predynastic workers' cemetery HK43 (Naqada I-IIC, c. 3750–3550 BCE) documents healed fractures in a well-nourished, robustly built population (Dougherty and Friedman 2008). The Old Kingdom Giza fracture study shows 93.3% successful fracture alignment in 2,287 long bones from 204 skeletons (Zaki 2013) — a tradition that requires an established practice predating the pyramid era.

The same integration of medical care extended to animals at Hierakonpolis before writing existed. The HK6 elite cemetery (c. 3800–3100 BCE) documents healed fractures in 20 of 38 wild mammals, including baboons, a leopard, a jungle cat, a hartebeest, an aurochs, and a hippopotamus; a cat shows healed fractures indicating at least 4–6 weeks of sustained captive care (Van Neer et al. 2015; Van Neer et al. 2014). This is the archaeozoological signature of what Schwabe (1978) called a 'fused' society; the full One Medicine framework and its corridor transmission significance are developed in Section 9.

Reverse-Pharmacology Precedent: Antibiotic Grain Storage

Mills, J.O. (1992). 'Beyond Nutrition: Antibiotics Produced through Grain Storage Practices, their Recognition and Implications for the Egyptian Predynastic.' In Friedman and Adams (eds), The Followers of Horus. Oxbow Monograph No. 20. Oxbow Books, Oxford, pp. 27–35. The

predynastic population at Hierakonpolis had access to conditions producing Penicillium-family antibiotic properties through grain storage. Published in a volume titled after the Shemsu Hor. The 1945 Nobel Prize in Physiology or Medicine (Fleming, Florey, Chain) confirmed penicillin's mechanism: Penicillium-family moulds on organic substrates kill bacterial pathogens. Primary sources: Fleming (1929, 'On the antibacterial action of cultures of a Penicillium,' British Journal of Experimental Pathology 10(3): 226–236); Chain, Florey et al. (1940, 'Penicillin as a chemotherapeutic agent,' Lancet 236(6104): 226–228). The mechanism is pharmacologically comparable. The Edwin Smith and Ebers papyri document the application of mouldy bread to infected wounds as a standard treatment.

Shamanic Precursors

Bestetti et al. (2024, Cureus, DOI: 10.7759/cureus.67195): predynastic shamans managed the healing process in predynastic Egypt. The Hierakonpolis population during the Naqada period would have included shamanic healers with access to the corridor's botanical resources. A 2025 chronological and stylistic analysis of the Hierakonpolis petroglyphs (Hardtke and Friedman 2025, in Förster et al. eds., Current Research in the Rock Art of the Eastern Sahara, IBAES 27, GHP London, pp. 171–190) provides updated attribution and dating for the rock art record at this integration node, consistent with the Naqada-period occupation documented in the skeletal and archaeobotanical evidence above.

Contemporary Validation: Honey

Honey's antibacterial properties are confirmed through hydrogen peroxide production, osmotic effect, low pH, and bee defensin-1 antibacterial peptides. Medical-grade honey is licensed as a medical product for professional wound care in Europe and Australia, with a 2025 comprehensive clinical review confirming efficacy across acute wounds, burns, and antibiotic-resistant infections (Barazesh et al. 2025, Health Science Reports, Wiley, DOI: 10.1002/hsr2.70240). The Edwin Smith and Ebers papyri document honey as a wound antiseptic: the application was consistent with confirmed pharmacological activity.

The Institutional Endpoint: Sais and the Temple of Neith

At the Sais temple complex in the western Nile Delta --- where the cult of Neith is attested from Naqada II (c. 3600--3350 BCE, predating the state by several centuries) --- a women's medical teaching institution is attested in later inscriptions. The teaching tradition is Middle to New Kingdom in its textual attestation, but the institutional roots in the cult of Neith — a goddess associated with war, weaving, and creation — predate unification. The Sais inscription quoted in Section 2 (Nunn 1996; Strouhal, Vachala and Vymazalová 2014) documents an institution; the antiquity of the Neith cult documents that Sais was a centre of female religious authority before writing existed. Whether the medical school itself dates to the predynastic period cannot be confirmed from current evidence — the teaching tradition is attested later, though the cult context is early.

The worship of Neith at Sais is confirmed from the Naqada II period (c. 3600–3350 BCE) — the corridor period, several centuries before unification (Wilkinson 2008; Hendrickx 1996). The institution's focus was gynaecology and obstetrics: the medical domain most directly documented in the corridor pharmacopeia (Acacia contraceptive, Artemisia post-partum, colocynth labour induction). Sais is in the western Nile Delta, Lower Egypt — the geographic destination of the Shemsu Hor migration. Peseshet (c. 2500 BCE, 4th Dynasty), 'Lady Overseer of Female Physicians,' is the earliest confirmed female physician in documented history; her title is attested from the tomb of her son Akhethetep at Giza (Harer and el-Dawakhly 1989,

‘Peseshet — the first female physician?’, Obstetrics and Gynecology 74(6): 960–961). No direct epigraphic link between Peseshet and the Sais institution has been established; the connection is inferred from the parallel between her title and the Sais women’s medical tradition, and is presented here as contextual, not confirmed.

From Shamans to Priests of Sekhmet

The Edwin Smith source text (c. 3000–2500 BCE) already mentions the parallel roles of the physician, the Priest of Sekhmet, and magicians — Sekhmet's physicians are present at the oldest surviving moment of the rational medical tradition. The full institutional timeline from predynastic shamans to Ni-Ankh-Sekhmet, and the significance of the Sekhmet priesthood's animal inspection role, are examined in Section 9 (Bestetti et al. 2024).

6. Reverse Tracking: From Egyptian Pharmacopeia to Corridor Source

This section tracks in the reverse direction: starting from what is documented in the Egyptian medical record and tracing each plant backward through the corridor nodes. The methodology is identical: E_eco documentation at each node, not E_seq causal claims. The purpose is to test whether the reverse direction yields independent corroboration and whether the botanical trail is structurally consistent with an origin in the Richat/Mauritanian zone.

Classification Criterion. A taxon is classified as a corridor-distributed plant if its native range or earliest documented domestication centre lies primarily within the Saharan–Sahelian ecological belt extending west–east across North Africa and connecting the seven corridor nodes examined in this paper (Richat Structure through Hierakonpolis), and if that range is distinct from Egypt’s indigenous Nilotic, Levantine, or Mediterranean ecological zones. This criterion was defined before classifying any taxon; the classification was not derived from the result. Each taxon is also evaluated by identification confidence: Confirmed (physical macroremains or secure chemical identification at a named site with a peer-reviewed publication); Probable (strong circumstantial evidence but no secure physical identification); Uncertain (candidate identification in primary literature explicitly noted as unlikely or unresolved). Only Confirmed taxa are included in the statistical proportions below.

Complete Pre-Unification Botanical Inventory. Table 3 below presents every currently documented plant taxon with confirmed physical presence in Egypt before or at unification (c. 3100 BCE), drawn from the peer-reviewed archaeobotanical record of the key sites: HK43, HK6, HK11C (Hierakonpolis), Abydos Tomb U-j, Naqada, Maadi, and Tell el-Iswid. Approximately 20–25 distinct taxa are currently confirmed; the table reflects published identifications and explicitly excludes unverified or contested attributions.

Taxon	Earliest Evidence in Egypt	Primary Source	Origin / Native Range	Corridor Status
Ricinus communis (castor oil)	c. 4000 BCE	Seeds in Egyptian tombs (Nunn 1996)	East African / Sahel	Confirmed Corridor
Lawsonia inermis (henna)	c. 3400 BCE	HK43 Burial 16, macroscopic color	North African /	Confirmed

		identification of henna dye on aged/white hair strands, confirmed by controlled replication (fresh Lawsonia inermis leaves ground and applied to modern hair samples, matching the archaeological color pattern); Fletcher, J. (1998), "The Secrets of the Locks Unraveled!", Nekhen News 10: 7–8	Sahelian	Corridor
Citrullus colocynthis (colocynth)	c. 3800 BCE	Seeds at Naqada (Nunn 1996)	North African Sahara / Sahel	Confirmed Corridor
Hyphaene thebaica (doum palm)	Predynastic	Predynastic tombs; Egypt = eastern Sahelian range terminus (Nunn 1996; Orwa et al. 2009)	Sahel-wide: Mauritania to Egypt	Confirmed Corridor
Artemisia seibeni	c. 3150 BCE	Terpenoid residues, Abydos Tomb U-j (McGovern et al. 2009, PNAS)	North Africa / Iran	Uncertain — McGovern notes identification 'unlikely at this early date'; excluded from statistics
Acacia nilotica	Predynastic	HK6 wood (Fahmy 2008)	Nile Valley native	Disqualified — native
Cyperus esculentus	c. 3750–3300 BCE	HK43 gut contents (Fahmy 2003)	Nile Valley native	Disqualified — native
Anethum graveolens (dill)	c. 3600 BCE	HK43 Burial 333 (Fahmy 2005)	North Africa / Mediterranean native	Disqualified — native to region
Ficus sycomorus	Predynastic	HK6 (Fahmy 2008)	Nile Valley	Disqualified —

			native	native
Ziziphus spina-christi	Predynastic	HK6 food offerings (Fahmy 2008)	Nile Valley / Near East native	Disqualified — native
Tamarix spp.	Predynastic	HK6 wood (Fahmy 2008)	Nile Valley native	Disqualified — native
Phoenix dactylifera (date palm)	Predynastic	HK6 rope fibre (Fahmy 2008)	Near East / North Africa native	Disqualified — native to region
Triticum dicoccum (emmer wheat)	Predynastic, ubiquitous	HK11C, HK43 (Fahmy et al. 2011)	Near Eastern domesticate	Disqualified — Levantine origin
Hordeum vulgare (barley)	Predynastic, ubiquitous	HK11C, HK43 (Fahmy et al. 2011)	Near Eastern domesticate	Disqualified — Levantine origin
Linum usitatissimum (flax)	Predynastic	HK11C (Fahmy et al. 2011)	Near Eastern domesticate	Disqualified — Levantine origin
Satureja (savory)	c. 3150 BCE	Terpenoid residues, Abydos Tomb U-j (McGovern et al. 2009, PNAS)	Mediterranean / North Africa native	Disqualified — native to region
Coriandrum sativum (coriander)	c. 3150 BCE	Terpenoid residues, Abydos Tomb U-j (McGovern et al. 2009, PNAS)	Levantine native	Disqualified — Levantine origin

Table 3: Complete pre-unification botanical inventory. The Corridor Status column applies the confidence classification defined in Section 6 (Confirmed / Chemically Attested / Probable / Uncertain / Disqualified); taxa marked Disqualified are Nile Valley, Levantine, or Mediterranean natives excluded from the corridor count. Four taxa involving contested identifications (Balanites aegyptiaca, Senna/Cassia, Commiphora africana, Moringa oleifera) are discussed in full below rather than in the table.

Four taxa — Balanites aegyptiaca, Senna (Cassia), Commiphora africana, and Moringa oleifera — involve contested identifications or documented scholarly disagreement that cannot be reduced to a single table cell without losing the argument; they are discussed in full below rather than in the table above.

Balanites aegyptiaca. Balanites aegyptiaca is attested in Egypt by c. 3600 BCE, in the HK43 Burial 333 basket (Fahmy 2005, Veg. Hist. Archaeobot. 14). Burial 333 is one of the richest graves in the non-elite HK43 cemetery, belonging to a woman aged 40–50; Friedman (2003) proposed on the basis of the full burial assemblage that she was a magico-medical practitioner,

since the basket contained Balanites fruits, stone amulets with carved faces, an incense mixture of partially burned nut grass tubers and coniferous wood fragments, bone awls, and various botanical remains recognised for their medicinal and antiseptic applications. The oldest confirmed pre-unification physical evidence of Balanites aegyptiaca in the Egyptian medical record therefore belongs to a proposed healer's burial. Balanites aegyptiaca fruits are also documented at Uan Muhuggiag, Tadrart Acacus, Libya (Node 3), dated 4450–3942 cal. BCE, co-occurring with Citrullus colocynthis seeds in the same pastoral assemblage (Wasylikowa and van der Veen 2004, Vegetation History and Archaeobotany 13: 213–217) — corridor Node 3 presence predates the Egyptian evidence by 400–600 years. Native range: Sahel-wide, from Mauritania to Egypt. Status: Confirmed Corridor.

Senna (genus Senna/Cassia). The Egyptian medical record documents primarily Cassia senna (Alexandrian senna, syn. Senna alexandrina), native to Upper Egypt and Nubia, while the Mauritanian pharmacopeia documents Senna italica (Senegal/Port Royal senna), native to the Sahelian belt. Both belong to the same genus, share the same active anthraquinone glycosides (sennosides), and are native to the Saharan–Sahelian corridor; the E_eco edge connects the genus across the corridor zone. Pottery residue from Abydos Tomb U-j, dated c. 3150 BCE, yields a compound-class-level identification — a terpenoid suite consistent with Cassia/Senna but not species-specific (McGovern et al. 2009, PNAS); McGovern et al. note the identification is 'not yet conclusive,' so this is treated as probable Senna pending further archaeobotanical confirmation (Schmelzer and Gurib-Fakim 2008, PROTA 11(1), PROTA Foundation, Wageningen). The Tomb U-j context is elite and contains Levantine wine jars manufactured in the Jordan Valley, confirmed by instrumental neutron activation analysis (McGovern et al. 2009, PNAS 106(18): 7361–7366); McGovern et al. distinguish explicitly between the Levantine origin of the wine jars and the botanical origin of the herbal additives, noting that Cassia is 'possibly native to Egypt' and that the non-Egyptian plants identified (Artemisia seibeni, Tanacetum annuum) are 'unlikely to have been traded or transplanted to Egypt at this early date.' Senna's documented native habitat is Egypt, Nubia, Arabia, and Sennar (Schmelzer and Gurib-Fakim 2008, PROTA 11(1)) — the Nile-to-Sudan corridor zone, not the Mediterranean or southern Levant. The botanical evidence in the Tomb U-j jars is therefore consistent with the corridor model and inconsistent with a Levantine import origin for the corridor plants specifically. Native range: Sahelian belt. Status: Confirmed Corridor.

Commiphora africana (myrrh). Commiphora africana (myrrh) is Chemically Attested in Egypt from c. 3000 BCE: general historical consensus places Egyptian use from this date (Nunn 1996; general historical record), and an aromatic plant extract consistent with Commiphora at compound-class level has been identified in Badarian/Naqada period funerary wrappings at Mostagedda, c. 4500–3350 BCE (Jones et al. 2014, PLOS ONE, PMC4132097), though species-specific archaeobotanical identification is still pending. The Kahun Papyrus (1825 BCE) provides the earliest textual attestation; no species-specific pre-unification physical find has been confirmed to date. Native range: Sahel, non-native to Egypt. Status: Confirmed Corridor.

Moringa oleifera. Moringa oleifera is attested from the Old Kingdom, c. 2700–2181 BCE — after unification, not before it — via Moringa oil found in pharaonic tombs including the Tomb of Maya, and in the Ebers Papyrus (1550 BCE) (Nunn 1996; Manniche 1989; Clapham and Rowley-Conwy 2007). Native range: Sahelian / East African. Status: Early Post-Unification Corridor (E_eco edge confirmed; Egyptian attestation begins in the Old Kingdom, not pre-unification).

Statistical Summary. The complete inventory identifies approximately 21 confirmed pre-unification taxa. Of these, 7 are classified as corridor taxa (Saharan/sub-Saharan distribution, non-native to Egypt), using the following three-tier evidential system: Confirmed = macroremain

physical evidence (actual plant material recovered archaeobotanically); Chemically Attested = GC-MS or spectroscopic compound-class identification in a dated archaeological context; Probable = general historical consensus or textual attestation, no specific physical or chemical find. Under this system: Ricinus communis (Confirmed: seeds in tombs from c. 4000 BCE), Balanites aegyptiaca (Confirmed: fruits at HK43 c. 3600 BCE; Takarkori c. 4450–3942 cal. BCE), Lawsonia inermis (Confirmed: physical hair specimen from HK43 Burial 16 with macroscopic henna-dye identification confirmed by controlled replication, c. 3400 BCE; Fletcher 1998), Citrullus colocynthis (Confirmed: seeds at Naqada c. 3800 BCE; Takarkori c. 4361–4000 cal. BCE), Senna italica/Cassia senna (Chemically Attested: compound-class terpenoid identification in Abydos Tomb U-j pottery c. 3150 BCE; McGovern et al. 2009 explicitly note the identification is not yet conclusive). A note on species and geography: the Senna species documented in Egyptian medicine is primarily Senna alexandrina (syn. Cassia acutifolia), known as Alexandrian senna, whose native range is confined to Upper Egypt and Nubia — the southernmost reach of the Saharan Highland Corridor — rather than the Lower Egyptian Nile Valley and Delta where the medical papyri tradition was codified and institutionalised. The commercial name “Alexandrian senna” derives not from the plant’s origin but from Alexandria’s role as the export port: the leaves were transported from Nubia and Sudan to Alexandria for distribution (HerbalGram, American Botanical Council; Kew Plants of the World Online). Its presence in the corpus is therefore consistent with introduction from the southern corridor zone into the Lower Egyptian institutional medical tradition, regardless of its Upper Nile nativity., Hyphaene thebaica (Confirmed: documented in predynastic Egyptian tombs from the earliest periods), and Commiphora africana (Chemically Attested: aromatic plant extract consistent with Commiphora resin at compound-class level in Badarian/Naqada period funerary wrappings at Mostagedda, Jones et al. 2014, PLOS ONE; species-specific identification pending). Commiphora africana is thus Chemically Attested Pre-Unification (compound-class level; species confirmation pending) — the Jones et al. 2014 GC-MS identification in directly AMS-dated funerary wrappings from c. 4500–3350 BCE constitutes genuine compound-class evidence, not merely historical consensus.

Two plants are classified as Old Kingdom corridor arrivals with transmission inference: Moringa oleifera (Old Kingdom tomb contexts, c. 2700–2181 BCE) and Cymbopogon schoenanthus (non-native to Egypt; corridor-distributed Mauritania to Sudan; kyphi named in Pyramid Texts c. 2400–2300 BCE; camel grass documented as core kyphi ingredient in every surviving recipe; physical remains in 21st Dynasty tombs at Deir el-Bahari; most parsimonious inference is arrival with the corridor population, awaiting pre-unification physical confirmation). Three late post-unification trade corridor arrivals (Hibiscus sabdariffa, Acacia senegal, Tamarindus indica) first appear in Egypt significantly after unification. One taxon (Artemisia seibeni) was evaluated as a corridor candidate but excluded because the primary source (McGovern et al. 2009) explicitly notes the identification as unlikely at this early date. Of the approximately 21 plants in the pre-unification corpus identified to species level with reasonable confidence, seven have specifically Saharan or sub-Saharan corridor distribution. The significance of this pattern is illuminated by comparison with the other documented stream of non-native plant introduction into predynastic Egypt. The predynastic archaeobotanical record at Tell el-Iswid, HK43, and Naqada documents a distinct Levantine and Mediterranean agricultural introduction stream: emmer wheat, hulled barley, dill, oregano, lentils, and field weeds typical of Near Eastern cultivation (Fahmy 2005; Fahmy et al. 2008). McGovern et al. (2009, PNAS 106: 7361–7366) document that southern Levantine herbs — rosemary, mint, thyme — accompanied the domesticated grapevine into the Nile Delta at c. 3000 BCE.

None of these Levantine or Mediterranean introductions appear in the pre-unification therapeutic medical corpus. The predynastic record therefore documents two geographically

and functionally distinct introduction streams entering Egypt at overlapping periods: the Levantine agricultural stream, which sorted into the food economy; and the Saharan corridor stream, which sorted into the therapeutic pharmacopeia. The sorting of non-native plants by functional domain — with the therapeutic corpus drawing from the corridor stream rather than the Levantine stream — is the pattern this paper proposes requires explanation. This is not a claim of statistical over-representation against an unestablished null model; it is a documented geographic and functional sorting pattern in the predynastic archaeobotanical record. Whether this proportion exceeds what Egypt's ecological position would produce by chance is a further, separate question that would require comparison against the equivalent proportions in other ancient pharmacopeias with documented non-native botanical content — Mesopotamian and Levantine medical corpora are the most direct comparators — and that comparison has not been undertaken here. Denominator methodology note: the denominator of 21 represents the subset of the Egyptian medical papyri's plant inventory that has confirmed or probable pre-unification archaeobotanical presence in Egypt (physical remains or residue analysis predating 3100 BCE), drawn from the approximately 30 plant species in the corpus that have been identified to species level with reasonable confidence in the peer-reviewed literature (Manniche 1989; Nunn 1996) out of approximately 160 hieroglyphic plant name entries across the papyri. The denominator of 15 is the subset of those 21 that are non-native to Egypt — excluding Nile Valley indigenous species (Salix mucronata, Ficus sycomorus, Ziziphus spina-christi, and similar Nilotic natives) whose presence in the corpus reflects local ecological availability rather than external introduction. The numerator of 7 is the subset of those 15 non-native pre-unification taxa whose native range is specifically Saharan or sub-Saharan corridor distribution, rather than Levantine, Mediterranean, or pan-tropical. Artemisia seibeni was evaluated as a corridor candidate and excluded because McGovern et al. (2009) explicitly flag its identification as unlikely at this early date. Commiphora africana is counted as Chemically Attested (not Confirmed) because the Jones et al. (2014) identification is compound-class level, not species-specific. These inclusion and exclusion criteria are stated explicitly so that the proportions can be reproduced, challenged, or refined by specialist archaeobotanical review. That approximately 47% of the identifiable external pre-unification taxa have specifically Saharan or sub-Saharan corridor distribution, rather than Levantine or Mediterranean origin, is the pattern this paper proposes requires explanation. These proportions establish that the Saharan botanical component of the pre-unification pharmacopeia is not marginal and is not adequately explained by Egypt's immediate ecological neighbourhood. A clarifying note on indigenous Egyptian plants: the willow serves as a control case.

The willow documented in the Egyptian medical papyri under the hieroglyphic name *trt* is the Nile Valley native *Salix mucronata* (safsaf willow), confirmed as indigenous to the Nile River canal system (Manniche 1989; Al Sherif et al. 2009), not a corridor import. It is attested across multiple papyri — the Edwin Smith Papyrus (Case 41, inflamed wounds), the Berlin Papyrus (toothache), the Brooklyn Papyrus (venomous bites), and the Ebers Papyrus (inflammation and appetite) — precisely because it was locally and abundantly available. Its presence in the corpus confirms that Egyptian physicians recorded effective plants regardless of geographic origin. The corridor hypothesis predicts exactly this: the Saharan component arrived with the Shemsu Hor, but Egypt's own indigenous pharmacopeia was already in use and continued to be documented alongside it. The indigenous Nile Valley pharmacopeia and the corridor pharmacopeia are complementary, not competing. (If a non-corridor, non-indigenous plant — e.g., a Levantine or Mesopotamian native — were confirmed in a pre-unification Egyptian medical context, this would weaken the hypothesis, as it would suggest systematic acquisition of external pharmacopeia through channels other than the corridor population.)

The seven confirmed/probable pre-unification corridor taxa, the two Old Kingdom arrivals, and the three post-unification trade arrivals set out above (Statistical Summary) together complete the network. All seven of the confirmed/probable pre-unification taxa are documented in the Mauritanian pharmacopeia: six in contemporary clinical surveys (Yebouk 2026; Ehel Adja 2025) and Lawsonia inermis in the Adrar Province ethnopharmacological record (Thouzery 1997). The evidence density for the Richat connection has now reached the level at which the under-excavation of Mauritania (Axiom 5) is the primary remaining limitation on confidence, rather than absence of any documentary trail.

1. Acacia (spp.)

Oldest Egypt evidence: Kahun c. 1825 BCE (contraceptive)
Corridor documentation: Tassili: albida, seyal (Hammiche 2006)
Mauritania/Richat documentation: Mauritania: A. senegal (Yebouk 2026); post-unification arrival in Egypt
Confidence: High (Tassili); Moderate (Mauritania)

2. Balanites aegyptiaca

Oldest Egypt evidence: Egyptian traditional medicine
Corridor documentation: Tassili (Hammiche 2006); Takarkori archaeobotanical (di Lernia et al. 2024)
Mauritania/Richat documentation: Most cited plant in Ouadane/Adrar surveys (278 UR; Yebouk et al. 2020); Thouzery 1997 Adrar list
Confidence: High (Takarkori physical evidence)

3. Artemisia (spp.)

Oldest Egypt evidence: Ramesseum Papyri c. 1800 BCE (post-partum)
Corridor documentation: Tassili: campestris + judaica (Hammiche 2006)
Mauritania/Richat documentation: North Africa wide; corridor native
Confidence: High

4. Citrullus colocynthis

Oldest Egypt evidence: Seeds at Naqada 3800 BCE; Ebers rheumatism
Corridor documentation: Seeds in Libya (corridor zone) 3800 BCE; Saharan native
Mauritania/Richat documentation: Saharan/Mauritanian distribution
Confidence: High (simultaneous archaeobotanical)

5. Hibiscus sabdariffa

Oldest Egypt evidence: Ebers 1550 BCE; domesticated Sudan 4000 BCE
Corridor documentation: Sudan domestication 4000 BCE = corridor node
Mauritania/Richat documentation: Mauritania: Ehel Adja Clinic (2025)
Confidence: Moderate

6. Senna (Senna italica)

Oldest Egypt evidence: Pottery residue Egypt 3150 BCE
Corridor documentation: North African native
Mauritania/Richat documentation: Mauritania: Ehel Adja Clinic (2025)
Confidence: Moderate

7. Moringa oleifera

Oldest Egypt evidence: Egypt from 3000 BCE (Old Kingdom)
Corridor documentation: Sahel/West African origin (Burkill 1995). Egypt attested from Old Kingdom contexts (c. 2700–2181 BCE): moringa oil in pharaonic tombs including Tomb of Maya (Nunn 1996; Manniche 1989), and in the Ebers Papyrus — both post-dating the Naqada II window by several centuries. The earliest secure archaeobotanical identification in the Nile corridor region is Moringa peregrina fruits at Qasr Ibrim, c. 700 BCE (Clapham and Rowley-Conwy, in Cappers 2007, Fields of Change, pp. 157–164). Moringa is therefore reclassified as an early post-unification corridor arrival — consistent with incorporation during or after state formation — distinct from the confirmed and probable pre-unification corridor taxa.
Mauritania/Richat documentation: Mauritania: Ehel Adja + Yebouk 2026
Confidence: Moderate (preserves the E_eco corridor edge; the difference is temporal, not geographic)

8. Tamarind (Tamarindus indica)

Oldest Egypt evidence: Ebers 1550 BCE (laxative)
Corridor documentation: North African distribution
Mauritania/Richat documentation: Mauritania: Ehel Adja Clinic (2025)
Confidence: Moderate
Note: Post-unification corridor arrival

9. Castor oil (Ricinus communis)

Oldest Egypt evidence: Tombs 4000 BCE; entire chapter in Ebers
Corridor documentation: 'Atlantic coast to Red Sea' = corridor-wide native
Mauritania/Richat documentation: Atlantic distribution includes Mauritanian zone
Confidence: Moderate

10. Doum palm (Hyphaene thebaica)

Oldest Egypt evidence: Pharaonic tombs + papyri
Corridor documentation: Distribution traces entire corridor
Mauritania/Richat documentation: Mauritania and Senegal: explicit in species distribution (Adewale 2024)
Confidence: High

11. Fenugreek

Oldest Egypt evidence: Ebers (promote childbirth)
Corridor documentation: 'Cultivated around Saharan oasis since very early times' (Duke 1981)
Mauritania/Richat documentation: Morocco/Algeria commercial; Saharan-zone native
Confidence: Moderate

12. Henna (Lawsonia inermis)

Oldest Egypt evidence: Ebers 1550 BCE (astringent, wounds, diarrhea)
Corridor documentation: Native to northern Africa; corridor distribution
Mauritania/Richat documentation: North African native including Mauritanian zone
Confidence: Moderate

13. Commiphora africana

Oldest Egypt evidence: Ebers 1550 BCE; NOT native to Egypt
Corridor documentation: Sahel-wide; documented as NOT native to Egypt
Mauritania/Richat documentation: Adrar Province ('adress', polyvalent, 6 uses; Yebouk et al. 2020); Thouzery 1997; Ehel Adja Clinic (2025)
Confidence: Moderate (ethnobotanical; archaeobotanical evidence pending Prediction 11)

The following thirteen plants are tracked from the Egyptian medical record to the corridor and Richat/Mauritanian zone. All edges are E_eco (ecological continuity); no E_seq (causal transmission) is claimed. Confidence classes follow Section 1.

The chronological framework for these botanical threads is traced in Table 2, which presents the sequence of events — ecological, archaeological, and textual — independently of the plant inventory. Dates, contexts, and significance are listed in chronological order, with botanical evidence cross-referenced to the plant list above.

Date	Evidence type	Location	Plant / Knowledge / Significance
15,000–8,000 BP	Geological sediments (peer-reviewed)	Richat Structure, Mauritania	Freshwater deposits confirm ecological connectivity during African Humid Period; corridor habitable (Armstrong et al. 2023, Nature Communications 14: 5549; see also Paper I, Levy 2026a)
c. 9,000 BCE	Rock art — Round Heads period	Tassili n'Ajjer, Algeria (Node 2)	Ritual/religious figures (dancing, worship postures); ritual tradition predates pastoral period (Soukopova 2012)
c. 7,500 BCE	Archaeological — pastoral occupation	Nabta Playa, Egypt (Node 6)	Cattle herding community; sub-Saharan African osteological origin; herder profile = probable botanical knowledge source (Wendorf, F. and Schild, R. 1998, 'Nabta Playa and its role in northeastern African prehistory,' Journal of Anthropological Archaeology 17(2): 97–123)
Holocene (pre-3000 BCE)	Archaeobotanical — physical remains	Takarkori, Libya (Node 3)	Balanites aegyptiaca drupes 'among the most common archaeobotanical remains' at corridor pastoral site (di Lernia et al. 2024) — ONLY pre-3000 BCE corridor physical botanical evidence

Date	Evidence type	Location	Plant / Knowledge / Significance
4,000 BCE	Archaeobotanical — tomb finds	Egypt (pre-unification)	Castor oil (Ricinus communis) seeds in tombs; native range Atlantic coast to Red Sea = corridor-wide; 2,500 years before Ebers Papyrus
4,000 BCE	Domestication record	Sudan (corridor zone)	Hibiscus sabdariffa domesticated Sudan c. 4000 BCE (Murdock 1959; Fuller and Hildebrand 2013); corridor-native; post-unification arrival in Egypt (first attested Ebers Papyrus 1550 BCE); present in Mauritanian pharmacopeia
3,800 BCE	Archaeobotanical — seeds	Naqada, Egypt AND Libya (corridor zone)	Citrullus colocynthis seeds simultaneously at Naqada and in Libya; Saharan desert native; demonstrates corridor-Egypt botanical continuity at this date
3,600–3,350 BCE	Epigraphic / cult attestation	Sais, Lower Egypt (corridor destination)	Neith worship at Sais confirmed (Naqada II period); corridor period; women's medical school roots pre-date the state (Wilkinson 2008; Hendrickx 1996)
3,150 BCE	Archaeochemical — pottery residue	Egypt (unification window)	Chemically Attested Senna (Cassia/Senna terpenoid signature; McGovern et al. 2009 note identification "not yet conclusive" at compound-class level); now in Mauritanian pharmacopeia; pre-writing, pre-papyrus; awaits species-specific archaeobotanical confirmation
3,000 BCE	Historical record — Old Kingdom	Egypt	Moringa oleifera in use from Old Kingdom tomb contexts (c. 2700–2181 BCE, early post-unification); now in Mauritanian pharmacopeia; arrival at or immediately after unification (Nunn 1996; Manniche 1989; Clapham and Rowley-Conwy

Date	Evidence type	Location	Plant / Knowledge / Significance
			2007)
c. 3,000 BCE	Linguistically reconstructed source text	Egypt	Edwin Smith source text: 47/48 rational cases; first written description of the brain, meninges, pulse-heart relationship; honey and mouldy bread (Nobel Prize 1945 mechanism)
c. 2,500 BCE	Epigraphic — tomb inscription	Giza, Egypt	Peseshet: 'Lady Overseer of Female Physicians'; earliest confirmed female physician (Harer and el-Dawakhly 1989); title attested from Giza tomb; possible but unconfirmed connection to Sais women's medical tradition
1,825 BCE	Surviving medical text (oldest)	Egypt — Kahun Papyrus	Acacia gum contraceptive; 34 purely empirical cases; NO magic; herder observation as probable origin (Haimov-Kochman 2005)
1,800 BCE	Surviving medical text	Egypt — Ramesseum Papyri	Artemisia post-partum; same genus/application as Tassili pharmacopeia; 2015 Nobel Prize genus (artemisinin)
1,550 BCE	Surviving medical text	Egypt — Ebers Papyrus	Comprehensive; 877 rubrics; all confirmed and probable pre-unification corridor plants present, plus Old Kingdom corridor arrivals (Moringa, Cymbopogon) and post-unification trade arrivals (see Section 6 Statistical Summary for full classification), plus Hibiscus sabdariffa, Acacia senegal, and Tamarindus indica (corridor-native post-unification arrivals); mixed rational/magical; rational layer from older 12th Dynasty sources
1,300 BCE	Surviving medical text	Egypt — London Medical	25 medical, 36 magical; magical overlay now dominant in general corpus

Date	Evidence type	Location	Plant / Knowledge / Significance
		Papyrus	
1,200 BCE	Surviving medical text (specialized treatise)	Egypt — Chester Beatty VI	Purely rational, NO magic; 41 proctological prescriptions; honey, myrrh, acacia, balanites confirmed. Jonckheere 1947: 'systematic absence of magical infiltrations confers the value of a scientific document.' Specialized texts maintained rationality throughout.
c. 450 BCE	Surviving medical text	Egypt — Brooklyn Papyrus	Mostly magical; rational empirical core buried under institutional overlay
Living (documented 2006)	Ethnobotanical survey — TEK oral tradition	Tassili n'Ajjer, Algeria (Node 2)	Tuareg Tamahaq pharmacopeia: Acacia, Artemisia (post-partum), Balanites, Artemisia judaica (parasites) — same plants, same applications as Egyptian papyri (Hammiche and Maiza 2006)
Living (documented 2024)	Archaeobotany + living TEK	Takarkori, Libya (Node 3)	Tuareg Kel Tadrart still use same Balanites medicinally today as in Holocene pastoral period; continuous from pre-3000 BCE to present (di Lernia et al. 2024)
Living (documented 2025–2026)	Ethnobotanical survey — TEK oral tradition	Mauritania / Richat zone (Node 1)	133 medicinal plants (Yebouk 2026); seven documented with correspondence to the corridor botanical suite: Acacia senegal, Senna italica, Moringa oleifera, Tamarindus indica, Hibiscus sabdariffa, Commiphora africana (Yebouk 2026; Ehel Adja 2025), and Lawsonia inermis (Thouzery 1997, Adrar Province ethnopharmacology). Of these, Senna, Commiphora, and Lawsonia have pre-unification presence in Egypt; Moringa is attested from Old Kingdom tomb contexts (early post-unification); Hibiscus, Acacia senegal, and Tamarindus are

Date	Evidence type	Location	Plant / Knowledge / Significance
			corridor-native post-unification arrivals. Pastoral TEK persists 'over millennia' (Ecology and Society 2025)

Table 2: Complete chronological timeline of all evidence — corridor, Egyptian, and living oral tradition. The timeline runs from the African Humid Period geological foundation through the pre-papyrus archaeobotanical record, the papyri corpus, and the living pharmacopeias documented in the corridor today. Three points of convergence stand out: (1) the pre-papyrus Egyptian botanical evidence (4,000–3,000 BCE) falls within the AHP corridor window, not after it; (2) Chester Beatty VI demonstrates that specialized technical texts preserved their rational character even in the Ramesside period; (3) the living corridor pharmacopeias (Tassili, Takarkori, Mauritania) are continuous from Holocene pastoral origins to the present.

Negative Cases. A fair test of the transmission hypothesis requires asking not only which corridor plants appear in Egyptian medicine but whether there are corridor plants that should appear — given their documented medicinal use and corridor presence — but do not. The selection filter hypothesis predicts the following criterion, stated in advance of the case analysis: plants transmitted to the corpus were those with broad, low-risk, multi-domain therapeutic applications manageable by non-specialist practitioners; plants with systemic cardiac or alkaloid toxicity requiring specialist dosage knowledge were not transmitted to the institutional corpus; food plants whose primary pastoral value is nutritional rather than pharmacological were not transmitted as therapeutics. This criterion is pre-specified and applied consistently to the three cases below — it is not derived from the cases themselves. The following preliminary analysis documents three corridor-zone plants from the Hammiche and Maiza (2006) Tassili N'Ajjer pharmacopeia that are absent from the Egyptian medical papyri corpus as documented in Manniche (1989) and von Deines, Grapow, and Westendorf (Grundriss der Medizin der Alten Ägypter, 1954–1973), alongside the corresponding transmission model interpretation.

Of the 80+ plants documented by Hammiche and Maiza (2006) at Tassili N'Ajjer, 13 are documented in the Egyptian medical corpus. The three negative cases below are drawn from the remainder; a full systematic analysis of all 67+ remaining species against the papyri corpus is identified as a research agenda item for future comparative ethnobotanical work. (1) Calotropis procera (Sodom apple; Arabic: tourha; documented at Tassili for skin diseases, dermatosis, and infected sores; Hammiche and Maiza 2006): confirmed present in the Egyptian Nile Valley flora by charcoal analysis at the predynastic sites of Adaïma and Elkab (Upper Egypt, c. 3500–3100 BCE; Fahmy 2005, Vegetation History and Archaeobotany 14), placing it physically in Egypt during the unification window. It is confirmed anti-inflammatory, antifungal, and analgesic, with documented use across the corridor arc from Mauritania through North Africa. Not identified by botanical name in the Egyptian medical papyri. Interpretation: its toxic latex profile (cardenolides; dose-dependent cytotoxicity) makes it a specialist plant with a narrow therapeutic window. On the transmission model, the corridor pharmacopeia was not transmitted wholesale but selectively — the plants with broad, low-risk, multi-domain pastoral applications were transmitted; plants requiring specialist knowledge to apply safely were not. Calotropis procera's confirmed presence in Egypt combined with its absence from the institutionalised corpus is the most informative negative case: it demonstrates that the transmission was selective, not comprehensive, and that the selection filter operated on risk

profile rather than geographic availability. (2) Panicum turgidum (desert millet; Arabic: merkba/markouba; documented at Tassili for digestive and nutritional conditions; Hammiche and Maiza 2006): archaeobotanically documented at Nabta Playa (corridor Node 6 zone) and at Farafra Oasis (Egyptian Sahara, mid-Neolithic, 7130–6190 BP), confirming its presence across the corridor and in Egypt from early periods. Its common name in Egypt and Arabia is 'taman/thaman', indicating Egyptian familiarity. Not identified in the Egyptian medical papyri as a therapeutic agent. Interpretation: Panicum turgidum is a food grass and forage plant; its pastoral use is primarily nutritional, not pharmacological.

The transmission model predicts transmission of the medicinal pharmacopeia, not every pastoral resource. A food grass whose pastoral value is caloric rather than therapeutic is not predicted to enter an institutionalised medical corpus. Its absence is expected under the model and uninformative as a negative case. (3) Ephedra (Ephedra alata subsp. alenda; documented at Tassili as Ephedra altissima for respiratory diseases and vascular conditions; Hammiche and Maiza 2006): native to Egypt (Sinai), Algeria, Libya, Mauritania, Morocco, Tunisia, and Western Sahara — native to Egypt itself and corridor-distributed. Tuareg pastoral communities of the Saharan corridor consume its fleshy cones as food and use the green stems, roots, and cones medicinally; the active compounds are ephedrine and pseudoephedrine, documented vasoconstrictors and bronchodilators. Not identified by botanical name in the Egyptian medical papyri despite Egypt's rich respiratory treatment tradition (Ebers 305–335). Interpretation: Ephedra contains ephedrine, a potent alkaloid with a narrow therapeutic window and significant cardiovascular toxicity at elevated doses. On the selection filter hypothesis, it falls in the same category as Calotropis procera — a pharmacologically active corridor plant excluded from institutional encoding because its risk profile made it unsuitable for a standardised corpus. Alternatively, the Egyptian corpus may have substituted Nile Valley respiratory plants for Ephedra's applications without preserving the species name.

The present evidence does not distinguish between these two explanations, and this case is therefore not counted as support for the selection-filter hypothesis. Preliminary interpretation: the three absent plants are informative in systematically different ways. Calotropis procera is the strongest negative case: physically present in predynastic Egypt, pharmacologically active, corridor-native, yet absent from the corpus — confirming that the transmission operated a selection filter based on risk profile rather than geographic availability. Panicum turgidum is uninformative as a negative case: its absence is predicted under the model because it is a food grass rather than a therapeutic agent. Ephedra is an inconclusive case: corridor-native, native to Egypt, pharmacologically powerful, yet absent from the corpus. Its absence is compatible with either a toxicity-based selection filter (as with Calotropis) or silent substitution by a Nile Valley respiratory plant, and the present evidence cannot distinguish between them. The hypothesis predicts not that every corridor plant was transmitted but that the specific suite with broad, low-risk, multi-domain pastoral therapeutic applications was. These negative cases are consistent with this prediction and are flagged for specialist evaluation.

7. Linguistic Corridor: The adr- Root as a Saharan Pastoral Ethnobotanical Marker

The adr- Root Across the Saharan Pastoral Network

Epistemic scope. This section documents the ethnobotanical, ethnomusicological, and toponymic record of Commiphora africana and its associated knowledge system across the

Saharan pastoral corridor. The evidence assembled here — the *adr-* name trail across six corridor nodes, the plant's documented use in pastoral commercial and musical material culture, and the cosmological naming cluster — constitutes a documented pattern of pastoral knowledge embedded in material culture, commercial practice, and oral tradition across the same geographic arc as the corridor migration model. This evidence is presented as what it is: a rich, independently documented record of how a specific plant was known, named, used, and culturally encoded by pastoral populations across the Saharan corridor. The *adr-* distribution is contextual ethnobotanical data that adds geographic coherence and cultural depth to the corridor model. The primary evidential pillars of this paper are the archaeobotanical record (Section 6), the chronological inversion of the medical corpus (Section 1), and the One Medicine integration at Hierakonpolis (Section 9). This section provides independent corroborating context from a different disciplinary domain; it does not independently establish transmission and is not claimed to do so.

Three structural limitations govern all inferences here. First, Berber underwent a major levelling episode around 100–200 CE that erased earlier linguistic diversity, making reconstruction of wild-plant names to the pastoral expansion period (5,000–4,000 BP) unlikely on current evidence (Blench 2021). Second, the absence of any *adr-* term in ancient Egyptian — where the plant was *ntyw*, an import term — is explained by language shift during integration, but this explanation is plausible rather than independently evidenced. Third, borrowing direction between Berber substrate and Hassaniya Arabic does not establish absolute chronological depth.

The *adr-* distribution. Burkill's authoritative ethnobotanical record (1985) documents the *adr-* name for Commiphora africana across the Saharan pastoral zone: *adras* (Tamachek, Mali), *adres* (Arabic, Mali), *adress* (Arabic, Niger), and *adras/adress/adriss* (Arabic [Maure], Mauritania and Senegal). Non-Saharan populations use unrelated names (Fula-Pulaar *badadi/badi*; Bambara *badi/barakanté*; Hausa *dashi/ikitchi*), confirming the *adr-* root as indigenous to the Saharan Berber pastoral network specifically — the network this paper proposes as the knowledge transmission pathway.

The *adr-* name trail constitutes four independently documented data points across the corridor: (1) the Mauritanian pharmacopeia at the Richat zone (Thouzery 1997; Yebouk et al. 2020; Burkill 1985); (2) the Tamachek Tuareg of Mali's Adrar des Ifoghas and Tassili n'Ajjer zone (Burkill 1985; Hammiche and Maiza 2006); (3) the Tuareg pastoralists of Illizi (Algeria/Libya border, Fezzan approach; Miara et al. 2019), whose pastoral profile (camels, cattle, sheep, goats) matches the Haimov-Kochman et al. (2005) knowledge-source identification; and (4) the Sudanese traditional pharmacopeia at the corridor's Egyptian terminus (University of Khartoum, 2025), documenting Commiphora africana resin in active use for inhalation, wound treatment, and oral health — precisely the application domains documented in the Egyptian medical corpus.

The name does not appear in sub-Saharan Niger-Congo or Chadic languages. It does not appear in ancient Egyptian (where the plant was *ntyw*, an import term). It is a Saharan Berber pastoral fossil, documented across the same geographic arc as the corridor migration model, carried by populations circumstantially linked, via the two-branch pattern documented in Section 9, to the deep Saharan lineage Salem et al. (2025) trace to the Takarkori node, and whose pastoral profile is structurally consistent with the herder-based knowledge source identified by Haimov-Kochman et al. (2005). The linguistic evidence does not prove transmission; it is structurally consistent with it at every documented node.

Historical depth. Whether *adras/adress* can be reconstructed to Proto-Berber or represents a later innovation within the Tuareg branch is a question for specialist comparative Berber linguistics and is beyond this paper's scope. Blench (2021) argues that the pastoral expansion was a primary Berber migration, explicitly rejecting the hypothesis that it was a separate vanished population; however, the levelling episode erases earlier linguistic diversity, making the inability to reconstruct *adr-* to Proto-Berber a consequence of levelling, not evidence against its antiquity.

A second, methodologically independent linguistic analysis reaches a broadly convergent conclusion by different means. Militarev (2021, Études et Documents Berbères 43(1): 133–160, DOI: 10.3917/edb.043.0135) uses lexicostatistics and glottochronology, rather than plant-name archaeobotany, to date the entry of Proto-Berber-Chadic speakers into North Africa and their subsequent spread throughout the Sahara to the onset of the Saharan rock-art “Pastoral Period,” beginning approximately 6,000 BCE. This sits within the broader AHP window this paper’s corridor model traces (Section 4, c. 15,000–5,000 BP), during which populations experienced repeated partial retreats to highland refugia across multiple generations before the final 3800–3100 BCE exodus toward the Nile; it does not itself establish presence at that later date. Two independent methods — Blench’s plant-name archaeobotany and Militarev’s lexicostatistics — therefore converge on the same broad conclusion: Berber-speaking populations were present and pastoral-dispersing across the Sahara during the AHP. They diverge sharply on geographic direction: Blench argues an eastern, Nile Valley origin dispersing west, the opposite of this paper’s corridor model, while Militarev’s Sahara-wide dispersal is directionally agnostic. This paper does not attempt to resolve that directional disagreement here, and notes only the narrower claim its linguistic evidence actually requires: that a Berber-speaking pastoral population inhabited the Sahara throughout the AHP.

The *adrar* toponym (pl. *idaren*) is documented in Herodotos (c. 500 BC) as a Berber geographical term, confirming pre-Islamic Saharan depth for the *adr-* root family across its topographic register.

Toponymic context. The Berber word *adrar* (Tifinagh: ⵄⴰⴷⵔⴰⵔ) means "mountain" or "highland plateau" and names every major highland refugium in the proposed corridor: Adrar Plateau (Mauritania, Richat zone), Adrar des Ifoghas (Mali), Adrar Province (Algeria), Adrar Afao (Tassili n'Ajjer), and Tadrart Acacus (Libya, Node 3). No peer-reviewed linguistic source establishes a shared etymological root between *adrar* (highland) and *adras* (Commiphora), and no such claim is made here. The co-occurrence is noted as geographic context, not as linguistic evidence of transmission.

The cosmological naming: *um el barka*. The Burkill (1985) ethnobotanical record documents a further Arabic name for Commiphora africana in Nigeria: *um el barka* (Vogel, cited in Burkill 1985; NIGERIA, ARABIC). The name translates as ‘mother of blessing’ or ‘mother of fortune’ — *umm* = mother; *al-barka* = blessing, grace, fortune. This is the *umm*-construction (‘mother of X’) applied in Arabic naming to convey that the named thing is the foundational or generative source of the quality it names. A plant called ‘mother of blessing’ encodes a cosmological status claim: the plant is conceived as the primal source of the healing power it delivers. This naming logic is structurally identical to the Salt Papyrus 825 encoding documented in Section 2: when Ra’s tears become myrrh, the plant’s healing is attributed to a divine generative source. Both the Arabic pastoral tradition and the Egyptian theological tradition independently encode the same plant under the same explanatory logic — a convergence consistent with the Heka transmission model. The companion name already documented in the *adr-* trail entry — *mbarkat* (Arabic, Niger) — is a variant of the same *barka/baraka* root (blessing, divine grace), confirming that the cosmological naming cluster is not confined to Nigeria but extends across the Niger-to-

Nigeria arc. Additionally, Burkill (1985) documents that the Tamachek distinguish *taghalbas* as the specific Tamachek name for the gum-resin produced by *adras*, distinct from the tree itself — demonstrating that Tuareg pastoral knowledge encoded a pharmacological distinction between the plant and its medicinally active resin, a level of botanical precision that substantially predates any formal taxonomy.

Material culture: wood use. Burkill (1985) documents that Commiphora africana is one of two woods — the other is Balanites aegyptiaca, the corridor's other flagship medical plant — used across the Saharan pastoral zone to carve standard market measures (nẹfga, mudel) for selling fruit, gum, henna leaves, and liquids, and is 'the wood used to make the Berber violin known as tidinit, an instrument of four strings of hair' (Burkill 1985, The Useful Plants of West Tropical Africa, Vol. 1, Royal Botanic Gardens, Kew). Variants of the tidinit are documented across the Sahel from Mauritania through Mali, Senegal, and Niger to the Saharawi communities of Algeria — the same corridor arc as the adr- name trail (Guignard 2005, Musique, honneur et plaisir au Sahara, Geuthner). The wood is documented as soft yet termite-resistant (Orwa et al. 2009) — easy to carve, durable in arid conditions. The same two plants this paper identifies as the corridor's flagship medical plants were therefore also selected, across the same pastoral zone, for precision-carved commercial and musical instruments, extending Commiphora's documented domains from medicine into craft. Whether Pastoral Period rock art depicts the tidinit or its ancestors is untested: the two documented multi-period Saharan rock art assemblages richest in potential musical content — the Tassili dance scene (Lhote 1958) and the Tadrart Acacus site of Ti-n-Anneuin, catastrophically vandalised in 2009 (di Lernia, Gallinaro and Zerboni 2010) — have not been examined specifically for instrument depictions (Prediction 7).

Research Agenda Items

The following observations are documented as research agenda items. They are independent of the botanical transmission argument and do not constitute evidence for it. They are presented under the same methodological constraints as all linguistic evidence in this paper (Axioms 1–3) and are explicitly flagged as Low confidence in Table S3.

Semitic naming tradition. The Hebrew *bedolach* (Genesis 2:12; on the location of Havilah, see Albright 1922; Müller 1992) and its Akkadian cognate *budulhu* name the same aromatic Commiphora resin in ancient Semitic sources; Pliny's *Natural History* (12:36) identifies a specifically Nubian variety as Commiphora africana; a germinated ancient Commiphora seed has since been chemically characterised and proposed as a possible connection to the species named in this Biblical/classical naming tradition (Sallon et al. 2024). The *adr-* (Berber pastoral) and *b-d-l* (ancient Semitic) naming traditions are linguistically unrelated; their independent documentation of the same non-Egyptian species from opposite ends of the corridor is noted as contextual only.

8. The Primary Botanical Threads

Thread	Corridor documentation	Egyptian text	Modern pharmacological confirmation
Acacia	Mauritania (Yebouk 2026)	Kahun 1825 BCE; Ebers 1550	Spermicide confirmed; still in modern contraceptive jellies

Thread	Corridor documentation	Egyptian text	Modern pharmacological confirmation
	+ Tassili (Hammiche 2006)	BCE	(Riddle 1992)
Balanites aegyptiaca	Tassili (Hammiche 2006) + Takarkori archaeobotanical (di Lernia et al. 2024)	Egyptian traditional medicine	84+ active compounds; antiplasmodial, antimicrobial, wound-healing (Shinde et al. 2025)
Artemisia	Tassili: post-partum + antiparasitic (Hammiche 2006)	Ramesseum Papyri (post-partum)	2015 Nobel Prize (Tu Youyou, artemisinin): standard malaria treatment worldwide
Doum palm	Mauritania to Egypt: distribution IS the corridor (Adewale 2024)	Pharaonic tombs + papyri	Confirmed antibacterial; broad pharmacological profile (J. Food Biochem. 2024)
Commiphora	Sahel-wide; Mauritanian pharmacopeia; NOT native to Egypt	Ebers + Egyptian embalming	Antimicrobial, anti-inflammatory confirmed; still in modern dentistry
Honey	Corridor-wide pastoral resource	Edwin Smith, Ebers (wound antiseptic)	Antibacterial confirmed (H_2O_2, low pH); medical-grade honey in clinical use (WHO)
Willow (Salix) — Nile Valley native; pharmacological parallel only	NOT a corridor plant. Salix mucronata (safsaf willow, Egyptian name trt) is indigenous to the Nile Valley and has been present in Egypt	Ebers (pain, anti-inflammatory)	Salicin from willow bark: precursor to aspirin; anti-inflammatory mechanism confirmed 1828 CE (Montinari, Minelli and De Caterina 2019). NOTE: willow is a Nile Valley indigenous plant, not a corridor import. The salicin-to-aspirin pharmacological chain documents what Egyptian

Thread	Corridor documentation	Egyptian text	Modern pharmacological confirmation
	since prehistoric times (Al Sherif et al. 2009; Manniche 1989). Not part of the corridor transmission argument; included here as a pharmacological parallel only.		physicians knew about a native Nile Valley plant independently of the corridor transmission argument.
Penicillium (mouldy bread)	Hierakonpolis (Mills 1992): grain storage antibiotics	Ebers, Edwin Smith (wound infection)	Nobel Prize 1945 (Fleming, Florey, Chain): identical mechanism

Table 4: Primary botanical threads with full pharmacological validation. Nobel Prize confirmations: Artemisia genus (2015) and Penicillium mechanism (1945). Note on Nobel Prize references: these citations document pharmacological validation of the mechanisms involved, not proof of historical connection between the Egyptian pharmacopeia and the prize-winning discoveries. The 2015 Nobel Prize confirmed the antiparasitic activity of the Artemisia genus; the Tassili and Takarkori species documented for post-partum care and antiparasitic use belong to the same genus but are not Artemisia annua, the specific artemisinin-producing species. The 1945 Nobel Prize confirmed the Penicillium mechanism; the Egyptian mouldy bread prescriptions (Ebers 499) employ a related biological principle without knowledge of the specific organism. Both references establish that the pharmacological knowledge embedded in the Egyptian corpus reflects genuine biological activity, not placebo or ritual effect. Note on Willow: Salix mucronata/safsaf is a Nile Valley native plant included here as a pharmacological parallel, not part of the corridor transmission argument. Its salicin-to-aspirin chain confirms the sophistication of Egyptian botanical medicine independently of the corridor hypothesis.

9. The Integration: Where Pastoral Knowledge Became State Medicine

The timeline traced in Section 5 converges on two institutional endpoints that together define where pastoral botanical knowledge was absorbed by the Dynastic state. Hierakonpolis (Node 7) represents the Upper Egyptian integration point, where Predynastic communities were already managing penicillin-producing grain stores, applying mouldy bread to wounds, and treating fractures successfully enough that healed breaks are documented throughout the HK43 skeletal population — a tradition of care consistent with the later, more precisely quantified Old Kingdom evidence (93.3% successful alignment at Giza; Section 6). Sais in the western Nile Delta, with cult attestation from Naqada II (c. 3600–3350 BCE), represents the Lower Egyptian

destination for the obstetrics and gynaecology thread of the pastoral pharmacopeia, although its institutional role as a dedicated medical training centre is documented only from the Middle Kingdom onward (see Table S2). The geographic range between these two endpoints encompasses the full corridor destination.

The specific institutional mechanism of absorption was the Per-Ankh — the Houses of Life. These temple-integrated institutions, whose oldest surviving references date to two royal decrees of the late Old Kingdom (c. 2200 BCE), were simultaneously scriptorium, medical school, library, and training centre under the protection of Thoth (Gardiner 1938, 'The House of Life,' Journal of Egyptian Archaeology 24(2): 157–179; Nunn 1996, Ancient Egyptian Medicine, British Museum Press, pp. 121–123). The Edwin Smith Papyrus — the most rational surviving medical text — preserves scribal signs in more frequent use in earlier periods than its own c. 1600 BCE copy date (see Series Context for the full dating debate), indicating that its knowledge base predates the institution that codified it. The hypothesis proposes that the Houses of Life were not the source of the medical knowledge; they were the institutional vessel into which an existing oral pastoral pharmacopeia was absorbed, codified, and distributed. Scribes meticulously copied the papyri and distributed them across Egypt (Gardiner 1938: 157–179). This copying and distribution is the mechanism by which the rational botanical pharmacopeia was standardised and spread — while the Heka theological framing developed around it across subsequent centuries.

The professional evolution documented by Bestetti et al. (2024, Cureus, DOI: 10.7759/cureus.67195) provides the institutional timeline with precision: Narmer's unification (c. 3100 BCE) converted shamanic healers into Sem priests responsible for the king's health; the Fourth Dynasty elevation of Ra (2613–2494 BCE) restructured the religious framework; the Fifth Dynasty (2494–2345 BCE) created the Priests of Sekhmet specifically to inspect bull meat for public safety during mass Ra festivities — which Bestetti et al. argue represents the first documented recognition of zoonotic transmission (an interpretation the paper notes, while acknowledging this reading is not consensus Egyptology). By 2487 BCE, Ni-Ankh-Sekhmet performed the first formally documented curative medical procedure. This sequence maps directly onto the Heka encoding model: the older the institutional layer, the closer to the original pastoral botanical knowledge it sits; the newer the layer, the more fully the theological framing has developed around it.

The Priests of Sekhmet represent the most specific evidence of pastoral veterinary knowledge institutionalized. Scholarly analysis of the wab-Sekhmet priest describes him as 'an expert in making medical diagnoses by observing blood circulation and the veterinarian responsible for the bull stables in the temples' — 'the only one with the ability to distinguish the living hypostases of the god Apis and enabled to certify the purity of the animals to be sacrificed' (Känel 1984; Torras Benezet 2021). The pure priests 'inspected the entrails of the beast and its blood, smelling and perhaps tasting it, to see if it was pure and free of disease.' This is precisely what pastoral herders do: they observe animal health daily, recognise disease in organs and blood, distinguish healthy from infected animals. The wab-Sekhmet did not invent this diagnostic practice — he institutionalized it within the state's ritual apparatus. The pastoral knowledge of the herd became the priestly knowledge of the sacrificial bull, encoded within the Sekhmet theological system. This is the Heka integration made concrete: the plant-based and animal-observation knowledge of the corridor pastoralists, preserved in the medical pharmacopeia, and administered by priests whose role was defined by the same empirical observation their pastoral predecessors had practised for millennia.

The institutional unity of human and animal medicine documented at Hierakonpolis has a formal scholarly framework. The 'One Medicine' or 'One Health' movement — now endorsed by the

World Health Organization, the Food and Agriculture Organization of the United Nations, and the World Organisation for Animal Health — traces its philosophical roots explicitly to ancient Egypt. Lerner (2013, 'The philosophical roots of the "One Medicine" movement,' Studia Philosophica Estonica 6(2): 97–109, DOI: 10.12697/spe.2013.6.2.07) traces the modern 'One Medicine' framework through its two principal intellectual founders: Rudolf Virchow and Calvin W. Schwabe. Schwabe's own lecture paper ('Comparative Medicine in Ancient Egypt: Origins of Early Biomedical Theories,' UC Davis, vetmed.ucdavis.edu) states directly: 'In virtually all ancient healing traditions no distinction was at first made between human and veterinary practice and Greek medicine, for example, began to separate into its two branches only in the third century BC. That fusion as "one medicine" also remains true of most traditional medical systems throughout the world today.' Schwabe further characterised predynastic Egypt as 'a fused society in which significant disciplinary and institutional separations were not yet evident between such currently diverse notions as animal husbandry, religion and healing' — a description structurally identical to the corridor pastoral world documented across Nodes 1–7 of this paper's framework. This was not Egypt's invention. It was the pastoral world's inheritance, brought by the corridor population and institutionalised into the Dynastic state.

The archival evidence for this unified tradition is preserved in the Kahun excavation itself. The Kahun Gynaecological Papyrus — already this paper's anchor evidence for Prediction 1 as the oldest surviving rational medical text — was found in the same physical document cache as the Kahun Veterinary Papyrus, a text treating cattle, dogs, birds, and fish with the same empirical, case-structured approach as the Edwin Smith. They were stored and published together by Griffith (1898, Hieratic Papyri from Kahun and Gurob, Bernard Quaritch, London; Gynaecological text: Plates V–VI; Veterinary text: Plate VII). The peer-reviewed translation of the Veterinary Papyrus, Walker (1964, 'The Veterinary Papyrus of Kahun: a revised translation and interpretation,' Veterinary Record 76: 198–200), confirms its rational, empirical character. Two medical traditions — one for humans, one for animals — were found together because they originated from the same tradition. They were never separated in the knowledge system that produced them. Their physical co-location at Kahun is the archival signature of the unified pastoral tradition that preceded writing. Schwabe (1978, Cattle, Priests, and Progress in Medicine, University of Minnesota Press) explicitly argued that this co-location reflects an original One Medicine knowledge system: 'At least some Egyptian priests were healers of both people and cattle,' and that this dual practice 'was a fused society in which the underlying biological observations which led to these theories' earliest at least implicit formulations in predynastic times, that is from the 4th millennium or earlier BC.'

The material record of bee products in the corridor extends the unified knowledge system back into the pre-papyrus pastoral window. Roffet-Salque, Dunne, Evershed et al. (2015, 'Widespread exploitation of the honeybee by early Neolithic farmers,' Nature 527: 226–230, DOI: 10.1038/nature15757) used lipid residue analysis of over 6,400 Neolithic pottery vessels across Europe, the Near East, and North Africa, identifying beeswax continuously from the seventh millennium BCE. North Africa is explicitly in their dataset — placing honey and bee product exploitation in the Neolithic North African pastoral zone of the corridor well before any Egyptian medical papyrus. Honey is documented in the Edwin Smith and Ebers papyri as a wound antiseptic, and its antibacterial mechanism (hydrogen peroxide, osmotic effect, low pH, bee defensin-1) is now clinically confirmed with medical-grade honey licensed in Europe and Australia (Barazesh et al. 2025, already cited in this paper). The question of when pastoral populations first applied honey to wounds cannot be answered by the papyri; it can be bounded: the knowledge was available, the material was in use, and the living successor pastoral cultures of the upper Nile — the Dinka and Nuer, whom Schwabe identifies as the closest surviving parallel to predynastic Egyptian cattle culture — are documented using ash from dung fires as

an antiseptic wound dressing on cattle (Schwabe 1978, Cattle, Priests, and Progress in Medicine, University of Minnesota Press). The knowledge that ash is antiseptic and that honey heals wounds was not invented in Egypt. It was documented in Egypt. The distinction matters for understanding the inversion: the knowledge was always there; what the papyri provide is its first written record. The gap in the corridor archaeozoological record is explicitly acknowledged. No systematic palaeopathological study of healed animal fractures has been conducted on the faunal assemblages at Takarkori, Messak Settafet, or Nabta Playa comparable to Van Neer et al. (2015) at Hierakonpolis. The bones exist at these sites — di Lernia et al. (2013, 'Inside the "African Cattle Complex,"' PLOS ONE 8(2): e56879, DOI: 10.1371/journal.pone.0056879) document extensive faunal assemblages at Messak Settafet; Wendorf, F. and Schild, R. (1998) document cattle remains at Nabta Playa; di Lernia et al. (2024, DOI: 10.1371/journal.pone.0310739) confirm adequate bone preservation conditions at Takarkori. They have simply not been examined for palaeopathological evidence of sustained care.

This is a research agenda item: if the Messak Settafet and Nabta Playa faunal assemblages were subjected to systematic palaeopathological analysis comparable to Van Neer et al. 2015, healed fractures in domestic cattle consistent with sustained human intervention would be expected on the One Medicine model. The current absence of such evidence reflects under-analysis, not under-excavation. The Hierakonpolis evidence stands as the corridor's currently documented earliest material record of the practice; the corridor gap awaits the fieldwork to close it. The Egyptian theological tradition had already unified these domains in a single divine figure: Nefertum (Nefertem), son of Sekhmet and Ptah in the Memphite triad, and simultaneously god of perfume, god of healing, and divine aromatherapist — attested in the Pyramid Texts from c. 2350 BCE (Wilkinson, R.H. 2003, The Complete Gods and Goddesses of Ancient Egypt, Thames and Hudson, pp. 184–185). Nefertum embodies the unity the paper argues arrived with the corridor population: the god of fragrant aromatic oils is simultaneously the god of healing, and his mother is Sekhmet — the goddess whose medical corpus this paper analyses. The Pyramid Texts entry for Nefertum (Spell 266) describes him as 'the lotus blossom which is before the nose of Ra' — an aromatic restorative healing the sun god's suffering — precisely the unification of scent and therapy that the corridor body-knowledge system encoded. The Egyptians did not simply practise medicine and perfumery separately. They had a god for their unity, and he was the son of the goddess of medicine.

The Unified Body-Knowledge System: Medicine, Gynaecology, Hygiene, Perfume, and Embalming as a Single Transmission

The preceding sections have tracked the corridor botanical suite through the Egyptian medical papyri. A structurally significant observation emerges when the analysis is widened: the same corridor plants do not define one Egyptian institutional domain — they define all of them simultaneously. The same botanical set underlies the Egyptian medical corpus, the gynaecological corpus, the perfume and aromatic industry, the soap and cleaning agents, the hair care and cosmetic tradition, and the embalming and mummification practice. This observation is not, by itself, decisive. A plant with genuinely versatile chemical properties — antimicrobial, surfactant, aromatic — can be independently discovered and adopted for medicine, hygiene, and preservation by any population with access to it, with no transmission event required; ethnobotanists have named this pattern ethnobotanical convergence (Garnatje, Peñuelas and Vallès 2017, 'Ethnobotany, phylogeny and 'omics' for human health and food security,' Trends in Plant Science 22: 187–191, DOI: 10.1016/j.tplants.2017.01.001). Distinguishing convergence from shared ancestry requires more than counting the number of domains a plant appears in. Teixidor-Toneu, Jordan and Hawkins (2018, 'Comparative phylogenetic methods and the cultural evolution of medicinal plant use,' Nature Plants 4: 754–

761, DOI: 10.1038/s41477-018-0226-6) formalise the discriminating tests: a use test (is the application shared or divergent between populations), a linguistic test (are the names for the plant cognate, indicating shared descent, or independently coined), and an ancestry test (does the distribution of use track a genealogical relationship between the populations, rather than mere geographic proximity). This paper's multi-domain evidence is assessed against all three. The use test is what the domain map below documents. The linguistic test is partly met: the adr- root documented across corridor nodes in Section 7 is a cognate name persisting across six corridor populations, establishing that the source tradition was linguistically continuous rather than independently coined at each node. It does not persist into ancient Egyptian, where the plant is instead ntyw, an import term (Section 7); the account offered there for this gap — language shift during integration — is plausible but not independently evidenced. The linguistic test therefore supports the coherence of the corridor source population but not, on its own, the specific transmission step into Egypt. The ancestry test is partially met, through a two-branch pattern that is itself informative. Salem et al. (2025) establish that the Takarkori lineage's closest ancient affinity is to the Taforalt population of Morocco (15,000 BP). Among present-day populations, this deep ancestral pool shows two distinct modern echoes, running in two different directions. Southward, Takarkori itself shows its strongest present-day affinity to Fulani herders sampled across eight Sahelian countries — the 'FulaniA' cluster, first identified by D'Atanasio et al. (2023, Current Biology 33(24): 5495–5504, DOI: 10.1016/j.cub.2023.10.075) and independently corroborated by Fortes-Lima et al. (2025, American Journal of Human Genetics 112(2): 261–275, DOI: 10.1016/j.ajhg.2024.12.015); Salem et al. note that this Fulani signal shares less drift with Taforalt specifically than with Takarkori. Within the Maghreb and western Sahara, by contrast, the Taforalt component itself is carried most strongly not by Fulani but by Saharawi and other Berber-speaking populations, at statistically significant levels (Serra-Vidal et al. 2019, Current Biology 29(22): 3953–3959.e4, DOI: 10.1016/j.cub.2019.09.050; outgroup-f3 = 0.218–0.222, Mann-Whitney $p = 4.52\times10^{-15}$). Saharawi communities and the Hassaniya-speaking Bidhan/Haratine communities of Mauritania whose pharmacopeia this paper documents botanically are the same broad ethnolinguistic population, divided by a twentieth-century colonial border: both descend from the same historical fusion of Beni Ḥassān Arab tribes with Sanhaja Berber populations, and both speak Hassaniya Arabic. This is the geographically and historically relevant branch for this paper's corridor model, which traces a population that remained in the western Sahara/Maghreb rather than moving south into the Sahel. No study has yet compared the ancient Takarkori or Taforalt genomes directly against modern Saharawi or Mauritanian samples; the chain here runs through Taforalt as an intermediate population, not through a direct test, and this link therefore remains circumstantial rather than confirmed. On the Teixidor-Toneu framework, a use pattern drawn from a linguistically coherent source population is better explained by shared ancestry than by independent convergent discovery when the ancestry test is fully met; with the ancestry test only partially and indirectly met here, that inference is correspondingly weaker here — though convergence cannot be excluded for any single plant considered alone, the linguistic test does not itself bridge to Egypt, and the multi-domain pattern is treated in what follows as evidence to be weighed alongside the corridor's other evidentiary pillars, not as proof on its own.

Balanites aegyptiaca — confirmed pre-unification at HK43 Burial 333, c. 3600 BCE — is called the 'soap berry tree' in English for documented reason. Its bark and roots lather in water and are documented as a soap substitute across its entire range from Mauritania to Sudan to Egypt (Burkill 1985, The Useful Plants of West Tropical Africa, p. 521). Its saponins — steroidal saponins, sapogenins, and diosgenins — are the active surfactant compounds; their broad pharmacological profile including surfactant and molluscicidal activity is comprehensively documented (Thakkar et al. 2025, Phytomedicine Plus 5(2): 100804; Shinde et al. 2025). In the Mauritanian Adrar zone specifically — the zone containing the Richat Structure — Balanites

aegyptiaca fruit is documented as used in the manufacturing of soap and cosmetic products (Abdelaziz et al. 2020, Plants 9(3): 401, DOI: 10.3390/plants9030401). Simultaneously, balanos oil from Balanites aegyptiaca was one of only two carrier oils preferred above all others by ancient Egyptian perfumers for its neutral odour and resistance to rancidity (Manniche 1999, Sacred Luxuries, Cornell University Press). The same tree that the corridor pastoralists used to wash themselves and their textiles became the primary carrier oil of the Egyptian perfume industry — because it arrived with both functions already established.

Two further dimensions of Balanites aegyptiaca in the Egyptian papyri complete the picture and illuminate the pastoral logic most directly. First, the Ebers Papyrus ear section (rubric 764) explicitly names 'fresh balanite oil' as the primary treatment for impaired hearing: 'The beginning of remedies for an ear whose hearing is poor: red ochre, juice of tamarix, are ground fine with fresh balanite oil' (Ebers Papyrus rubric 764; von Deines, Grapow, and Westendorf 1954–1973, Grundriss der Medizin der alten Ägypter). This places Balanites in the ENT section of the oldest comprehensive medical text — a seventh institutional domain alongside medicine, perfume, soap, hair care, embalming, and pest control. Second, and most significant for the pastoral logic argument: Balanites aegyptiaca has confirmed molluscicidal and cercariacidal activity — its saponins kill the freshwater snails and copepods that serve as intermediate hosts for schistosomiasis and guinea worm; aqueous extracts exhibit molluscicidal activity against Biomphalaria pfeifferi and Lymnaea natalensis, and cercariacidal activity against Schistosoma mansoni cercariae (Molla et al. 2013; Shinde et al. 2025). Guinea worm (Dracunculus medinensis) is already documented in this paper's Table 1 as treated in the Ebers Papyrus by a method unchanged to the present. The Ebers Papyrus itself documents the treatment of guinea worm. Balanites aegyptiaca kills the copepod that transmits guinea worm. A pastoral population herding cattle, camels, sheep, and goats at Sahelian water sources — where schistosomiasis and guinea worm are endemic — would not simply know that Balanites cleans the body. They would know that Balanites cleans the water. The saponin emulsion from Balanites fruit or bark is toxic to the snail and copepod vectors but does not affect mammals, and fish killed by it remain edible (Orwa et al. 2009, World Agroforestry Centre species database; Thakkar et al. 2025). This is not a coincidental property. This is the most practically critical knowledge a pastoral people in parasite-endemic Sahelian environments could possess: the plant that grows along their water sources, that their camels browse extensively, that they use to wash their bodies and clean their textiles, simultaneously kills the parasites in the water their animals drink. The fact that Balanites is the primary Egyptian perfume carrier oil, the primary soap agent, and the specific treatment for guinea worm in the Ebers Papyrus is, on the transmission hypothesis, consistent with a population that arrived at the Nile already knowing every property of this plant simultaneously, because their survival had depended on that knowledge for generations in the environments where the plant grows. Independent discovery of each application within Egypt cannot be excluded for Balanites considered alone; the case for transmission rests on this pattern recurring across multiple, chemically unrelated plants with the same linguistic and ancestry support set out above, not on Balanites in isolation.

Ricinus communis (castor oil) — confirmed pre-unification in Egyptian tombs from c. 4000 BCE — is simultaneously documented as a medical oil (Ebers Papyrus rubric 251), a hair growth agent (Ebers rubrics 437–476, the dedicated hair chapter: 'the castor oil plant as promoting hair growth in women'), a perfume ingredient, and a primary cleaning agent. An Egyptian text from 210 BCE instructs the supply of castor oil and mineral natron for the cleaning of flax in bleaching houses — and castor oil, unusually among vegetable oils, does not require boiling to be saponified by natron, meaning proto-soap was a by-product of every textile-cleaning operation using these two substances together (documented in an Egyptian administrative text of c. 210 BCE specifying castor oil and natron for flax bleaching; cited in the history of soap-making

literature as the earliest Egyptian cleaning agent record). In the 2023 Saqqara embalming workshop analysis, castor oil was confirmed specifically as the treatment agent for the head during mummification (Rageot et al. 2023, Nature 614: 287–293, DOI: 10.1038/s41586-022-05663-4). One plant, present in Egypt before writing existed, deployed across medicine, hair care, perfumery, textile cleaning, and embalming — a pattern consistent, on the same combined evidence, with these uses arriving together rather than being independently discovered, though as with Balanites this case does not stand alone. A further dimension: Ricinus communis is documented as a traditional anti-fertility agent, its seed extract showing anti-implantation and estrogenic activity in animal studies (Chouhan et al. 2021, 'Medicinal Properties of Ricinus communis: A Review,' International Journal of Pharmaceutical Sciences and Research 12(7): 3632–3642, DOI: 10.13040/IJPSR.0975-8232.12(7).3632-42; Brahmi et al. 2025, Diseases 13(5): 160, DOI: 10.3390/diseases13050160). Balanites aegyptiaca is likewise recorded as a traditional contraceptive (Chothani and Vaghasiya 2011, Pharmacognosy Reviews 5(9): 55–62, DOI: 10.4103/0973-7847.79100). These are two confirmed pre-unification corridor plants independently used in reproductive-health management by corridor communities today — the pastoral population that understood both as soap and medicine also understood their gynaecological applications.

Lawsonia inermis (henna) — confirmed pre-unification at HK43 via a physical hair specimen with macroscopic dye identification and controlled replication (Fletcher 1998), c. 3400 BCE — carries the same multi-domain profile. It is documented in the Ebers Papyrus as an astringent that closes wounds and stops diarrhoea. It was historically applied to the hands and feet to protect against fungal pathogens and to hair to combat lice and dandruff (Semwal, R.B.K. et al. 2014, 'Lawsonia inermis: ethnobotanical, phytochemical and pharmacological aspects,' Journal of Ethnopharmacology 155(1): 80–103, DOI: 10.1016/j.jep.2014.05.035). The Cyprinum perfume — one of the most widely documented ancient Egyptian perfume formulas — was based upon the scent of henna (Lawsonia inermis) combined with cardamom, cinnamon, myrrh, and southernwood (Manniche 1999, Sacred Luxuries, Cornell University Press). Henna was used as a mummification material: one 11th Dynasty mummy showed fingernails tinted with henna; an 18th Dynasty mummy displayed reddish-dyed hair (Lucas, A. and Harris, J.R. 1962, Ancient Egyptian Materials and Industries, 4th ed., Edward Arnold, London). For a pastoral population living in close proximity to animals in hot desert conditions, henna's antimicrobial properties — confirmed against fungal pathogens, lice, and bacteria — would have been among its most practically important applications, predating any cosmetic or ritual use.

Commiphora africana (myrrh resin) — Chemically Attested pre-unification, with the Jones et al. 2014 (PLOS ONE, PMC4132097) aromatic plant extract at Mostagedda representing the earliest possible evidence — is confirmed across the same six domains. It is the bridge plant that crosses from medical to ritual in the Salt Papyrus 825 (Ra's tears becoming myrrh). It is the core of the Mendesian perfume formula. It is confirmed in the Saqqara mummification workshop vessels. And the Jones et al. 2014 Mostagedda study — already cited in this paper for the Commiphora compound-class identification — contains a finding whose full significance has not previously been noted: the embalming agents identified in the Badarian and Predynastic funerary wrappings (c. 4500–3350 BCE) constitute 'complex, processed recipes of the same natural products, in similar proportions, as those utilized at the zenith of Pharaonic mummification some 3,000 years later' (Jones et al. 2014, PLOS ONE 9: e103608, DOI: 10.1371/journal.pone.0103608). The evidence is consistent with the hypothesis that this recipe arrived as an integrated system rather than being assembled incrementally within Egypt. A pre-literate pastoral population was already wrapping its dead in complex multi-ingredient aromatic preservative recipes before Egypt was Egypt, and those recipes were transmitted with sufficient fidelity that 3,000 years of Pharaonic practice did not substantially alter them. On the

transmission model, this is the corridor visible in the funerary domain: not a gradual development, but an inherited practice carried intact to the Nile. Jones et al. (2018, Journal of Archaeological Science 100: 191–200, DOI: 10.1016/j.jas.2018.07.011) confirmed this finding on a second independent site and an intact mummy. Turin Mummy S. 293 (Egyptian Museum Turin), radiocarbon-dated to 3635–3380 cal BCE (Naqada IA–IIB, at 95.4% confidence), was chemically analysed by GC-MS and found to contain the same embalming recipe: plant oil as the dominant component, with conifer resin (heated, confirmed by methyl esters indicating processing), aromatic plant extract, and plant gum/sugar. The Turin mummy originates from Upper Egypt (Gebelein/Qena/Luxor area) — a different region from Mostagedda in Middle Egypt. The same recipe, at the same proportions, in two independent Upper Egyptian sites, at 3700–3350 BCE. The paper's conclusion states explicitly: 'this recipe contained antibacterial agents, used in similar proportions to those employed by the Egyptian embalmers when their skill was at its peak, some 2500 years later' (Buckley, in Jones et al. 2018). The geographic spread confirms what the Mostagedda evidence alone could not: the formative embalming recipe was not a localised practice but pan-Upper Egyptian at a time when, as Jones et al. 2018 note, 'the concept of a pan-Egyptian identity was supposedly still developing.' The recipe preceded the state that institutionalised it. Critically, Jones et al. (2018, p. 198) flag an unanalysed parallel at the corridor's integration node: 'This may reflect the reported early use of layers of linen impregnated with a "resinous" substance wrapped around the back of the head, jaw and hands in particular at Hierakonpolis, Cemetery HK43. Biochemical analyses have not been carried out, hence the nature and composition of these residues at Hierakonpolis remain unknown (Friedman et al. 2002; Jones 2007).' The corridor plants already physically documented at HK43 — castor oil (4000 BCE), henna (3400 BCE), Balanites (Burial 333 basket) — are the candidate organic residues for exactly this unanalysed resinous substance. GC-MS analysis of the HK43 resin-soaked linen would test whether the embalming recipe documented at Mostagedda and confirmed at Turin was also operating at the corridor's destination node before any of the surviving papyri were written.

Moringa oleifera (Old Kingdom corridor arrival, c. 2700–2181 BCE) completes the picture. It became the second primary perfume carrier oil alongside Balanites, and was valued as a luxury hair conditioning and skin treatment oil — documented in New Kingdom contexts as a luxury oil — residue analysis of New Kingdom jars has identified Moringa (baq oil) alongside balanos and castor oil, and it appears in royal perfume and unguent inventories as a prestige product (Manniche 1999, Sacred Luxuries). Its arrival in the Old Kingdom, immediately after unification, follows the same pattern as the pre-unification corridor plants: non-native to Egypt, corridor-distributed, arriving with established multi-domain applications. The gynaecological corpus of the Egyptian medical papyri — the Kahun Gynaecological Papyrus (c. 1825 BCE), the Ebers Papyrus gynaecology section (rubric 783), and the Ramesseum Papyrus IV (c. 1700 BCE) — constitutes a seventh institutional domain for the corridor botanical suite, one not previously identified in this paper. The Ebers Papyrus rubric 783 prescribes a contraceptive suppository of acacia tips, dates, and honey: the acacia ferments to produce lactic acid anhydride, a confirmed spermicidal agent still used in modern contraceptive preparations (Riddle 1992; Thomas et al. 2020, Contraception: X 2: 100031). Citrullus colocynthis — confirmed pre-unification corridor plant from c. 3800 BCE, physically present in the same pastoral assemblage at Uan Muhuggiag alongside Balanites — is the active abortifacient ingredient in the Ebers contraceptive formula; its abortifacient properties are documented in the pharmacological literature and still observed in traditional Arabic medicine (Dehghani et al. 2008, 'Toxic effects of hydroalcoholic extract of Citrullus colocynthis on pregnant mice,' Iranian Journal of Veterinary Research 9(1): 42–45). The pastoral logic is direct: a population managing reproductive health in remote field conditions without institutional medicine would carry gynaecological plant knowledge with the same urgency as wound care, parasite control, and water purification. The same Citrullus colocynthis

seeds physically present in Egyptian contexts from 3800 BCE were carrying both their documented purgative and anti-inflammatory properties AND their abortifacient and anti-fertility properties. Both arrived at the Nile simultaneously, in the same seeds, with the same population. The Kahun Gynaecological Papyrus — the oldest surviving intact medical papyrus and the most purely rational of all the corpus — deploys corridor plants for their most intimate pastoral applications. On this hypothesis, the gynaecological corpus was transmitted alongside the medical, aromatic, and hygienic corpus because it came from the same source.

The structural argument this evidence supports is the following. A pastoral population living with cattle, camels, sheep, and goats in hot Sahelian desert conditions requires an integrated body-maintenance system covering wound care, parasite control, skin protection, odour management, hair hygiene, textile cleaning, and funerary preservation. Every one of these functions maps onto the corridor botanical suite. Balanites cleaned. Henna protected against parasites and fungi. Castor oil conditioned hair and treated skin. Commiphora preserved bodies and masked odour. Considered plant by plant, each of these applications could in principle have been discovered independently within Egypt — ethnobotanical convergence, not transmission, is the default explanation for any single multi-use plant. What favours transmission here is the combination of the three lines of evidence set out at the start of this section: the use pattern documented plant by plant above and mapped in Table 5 below; the linguistic pattern, the cognate adr- root persisting across six corridor populations rather than being independently coined at each (a fossil of source-population coherence, though it does not itself persist into ancient Egyptian; see Section 7); and the ancestry pattern, partially met: Salem et al. (2025) document deep Saharan lineage continuity from Taforalt through Takarkori, whose modern echoes split between a southward Fulani branch (D'Atanasio et al. 2023) and a Maghreb/western-Sahara branch carried by Saharawi populations (Serra-Vidal et al. 2019) ethnolinguistically continuous with the Hassaniya-speaking population that uses these plants today — the geographically relevant branch, though not yet directly tested against it. On the transmission hypothesis, when that population arrived at the Nile and was absorbed into the Dynastic state, the unified knowledge system was disaggregated into separate institutional domains: the medical papyri, the perfume industry, the embalming workshops, the cosmetic traditions. Modern scholars have studied each of these domains independently, which is precisely what this disaggregation would produce if it occurred 5,000 years ago: the disciplines that study each domain today reflect the same separation.

The Heka encoding model proposed in this paper explains not just the medical corpus inversion but the simultaneous appearance of the same plants across every Egyptian personal care domain: on the combined linguistic, ancestry, and use evidence, this pattern is consistent with a unified knowledge system arriving intact, more so than with convergent independent discovery in each domain — though the latter cannot be excluded for any single plant considered alone, and the supporting evidence has real limits: the genetic continuity Salem et al. (2025) document connects Takarkori to Taforalt, whose modern echo in the Maghreb/western Sahara (Saharawi populations; Serra-Vidal et al. 2019) is ethnolinguistically continuous with, but not yet directly tested against, the specific Mauritanian population documented botanically here, and the adr- root does not itself bridge into ancient Egyptian (Section 7). The multi-domain pattern is offered as evidence to be weighed alongside the paper's other pillars, not as decisive on its own. The six broad institutional categories — medicine, gynaecology, hair care, perfumery, soap/hygiene/textile care, and embalming — spanning sixteen distinct clinical and cultural subdomains mapped in Table 5 below (medicine alone accounting for eleven of the sixteen), are, on this model, the disaggregated fragments of a single pastoral body-knowledge tradition. The Kahun Gynaecological Papyrus (Section 1) is gynaecological in focus because reproductive health management was the most urgent priority for a pastoral population whose survival

depended on birth spacing, obstetric safety, and post-partum recovery in remote field conditions. On this hypothesis, it deploys corridor plants because those were the plants the population brought with them, already understood in their full gynaecological applications, before writing existed, before the state existed, and before any institutional mechanism could account for their presence in the Nile Valley.

Table 5 maps the corridor botanical suite across the full spectrum of Egyptian institutional categories — medicine, gynaecology, hair care, perfumery, soap/hygiene/textile care, and embalming — broken out into sixteen distinct clinical and cultural subdomains, showing the same plants appearing simultaneously across all of them, a pattern consistent with a unified knowledge system arriving intact.

The Book of Hearts and the Pre-Unification Timestamp. The most significant single finding to emerge from the domain analysis is the date of the source material for the Ebers Papyrus Book of Hearts. The Ebers Papyrus is not a unified composition: it is explicitly a compilation from earlier temple sources. The papyrus itself opens with the statement “I came forth from On (Heliopolis)” followed immediately by “I came forth from Sais,” indicating that the compiler extracted material from the medical libraries of multiple temple institutions (Withington 1892; Nunn 1996). The papyrus contains an internal self-dating statement of particular significance: paragraph 856a states that “the book of driving wekhedu from all the limbs of a man was found in writings under the two feet of Anubis in Letopolis and was brought to the majesty of the king of Upper and Lower Egypt Den” — a reference to the First Dynasty king Den (c. 2950 BCE), which Egyptologists identify as a historic anachronism placing the origin of at least some sections of the Ebers material closer to c. 3000 BCE (Nunn 1996, Ancient Egyptian Medicine, British Museum Press, p. 31, citing the wekhedu-text passage directly; Grundriss der Medizin der alten Ägypter, von Deines, Grapow, and Westendorf 1954–1973). The American Journal of Psychiatry citation of the Ebers Papyrus (Bou Khalil and Richa 2014, American Journal of Psychiatry 171) also explicitly states that the Book of Hearts constitutes “a collection of extracts from different existing sources dating as far back as 3400 BCE.” This broader dating — which extends the compilation window to 3400 BCE — reflects the general scholarly recognition that the Ebers sources predate the c. 1550 BCE copy date by a substantial margin, possibly reaching into the predynastic period. The Ebers Papyrus is in this respect directly analogous to the Edfu Building Texts: a New Kingdom document that explicitly preserves, copies, and attributes its content to much older sources, with internal referential markers that allow partial reconstruction of those earlier source dates.

The Book of Hearts covers cardiovascular function, depression, and dementia — and its corridor botanical prescriptions include Commiphora (headache and mood), castor oil, and henna. At the 3400 BCE horizon, henna is physically confirmed at Hierakonpolis (HK43 infrared identification, c. 3400 BCE). Colocynth is in the Naqada assemblages from 3800 BCE. Castor oil is in Egyptian tombs from 4000 BCE. The knowledge in the Book of Hearts and the physical presence of its botanical ingredients are contemporaneous at the pre-unification level. On this hypothesis, the written Book of Hearts is a 1550 BCE transcription of a knowledge system that was already operating when the corridor population reached the Nile — a reading consistent with both the internal self-dating evidence of the papyrus itself and the archaeobotanical record of the corridor plants it documents.

Table 5: Corridor Botanical Suite — Complete Domain Map Across the Egyptian Medical and Cultural Corpus. Colour coding: orange = domains with pre-unification source material dating; green = domains with pre-unification physical archaeobotanical evidence for corridor plants; blue = domains attested primarily post-unification. All domains contain confirmed corridor plants. The simultaneity across sixteen clinical and cultural

subdomains — spanning six broad institutional categories, with medicine alone accounting for eleven of the sixteen — from source material dating as far back as 3400 BCE, is, on the combined linguistic, ancestry, and use evidence set out above, consistent with a unified knowledge system arriving intact rather than independent convergent discovery in each domain.

Domain	Source Material Date	Primary Papyrus	Corridor Plants Documented	Earliest Physical Evidence in Egypt
Psychiatry / Mental Health (Book of Hearts)	c. 3400 BCE (Ebers Papyrus paragraph 856a internal reference to King Den, c. 2950 BCE, per Nunn 1996, p. 31; broader compilation window to 3400 BCE per Bou Khalil and Richa 2014, American Journal of Psychiatry 171)	Ebers Papyrus §854a–855z (Book of Hearts)	Commiphora (headache relief); Castor oil (base); Henna	Castor oil: 4000 BCE; Henna: 3400 BCE (HK43); Commiphora: Probable pre-unification
Cardiovascular / Circulatory System	c. 3400 BCE (same Book of Hearts source material)	Ebers Papyrus §855 (Treatise on the Heart)	Castor oil (rubric 251); Commiphora; Senna (purgative to clear channels)	Castor: 4000 BCE; Senna: Chemically Attested 3150 BCE; Commiphora: Chemically Attested pre-unification
General Medicine / Wound Care	c. 3000–2500 BCE (Edwin Smith source text; Pommerening 2014 genre classification)	Edwin Smith Papyrus; Ebers Papyrus; Hearst Papyrus	Castor oil (wound base); Henna (astringent, wound closure); Commiphora (antiseptic);	Castor: 4000 BCE; Colocynth: 3800 BCE; Balanites: 3600 BCE; Henna: 3400 BCE; Commiphora:

Domain	Source Material Date	Primary Papyrus	Corridor Plants Documented	Earliest Physical Evidence in Egypt
			Balanites (wound wash); Colocynth (anti-inflammatory)	probable
Gynaecology / Contraception / Obstetrics	c. 1825 BCE textual; oral tradition pre-unification (corridor population reproductive health management)	Kahun Gynaecological Papyrus (oldest surviving intact medical papyrus); Ebers §783; Ramesseum Papyrus IV; Berlin Papyrus	Colocynth (abortifacient, Ebers §783); Acacia senegal (lactic acid spermicide, Kahun); Castor (anti-ovulatory, corridor communities); Balanites+Ricinus contraceptive combination	Colocynth: 3800 BCE (Naqada; Uan Muhuggiag 4450–3942 BCE alongside Balanites); Castor: 4000 BCE
Digestive / Parasitology	c. 1550 BCE textual; purging tradition predates writing (Herodotus confirms monthly purging custom)	Ebers Papyrus (intestinal section); Berlin Papyrus	Castor oil (laxative, rubric 251); Senna (purgative); Colocynth (purgative); Balanites (antidiarrheal, antispasmodic, Rehman et al. 2022)	Colocynth: 3800 BCE; Castor: 4000 BCE; Senna: Chemically Attested 3150 BCE; Balanites: 3600 BCE
Respiratory / Coughs / Asthma	c. 1550 BCE textual	Ebers Papyrus §305–335	Castor oil (primary base, rubric 305–335); Commiphora (anti-inflammatory)	Castor: 4000 BCE; Commiphora: Chemically Attested pre-unification
Ophthalmology / Eye Diseases	c. 1550 BCE textual; Carlsberg	Ebers Papyrus eye section (§336–431); Carlsberg	Castor oil; Henna (antimicrobial	Castor: 4000 BCE; Henna: 3400 BCE

Domain	Source Material Date	Primary Papyrus	Corridor Plants Documented	Earliest Physical Evidence in Egypt
	Papyrus parallel	Papyrus	applications)	
Dentistry / Oral Health	c. 1550 BCE textual	Ebers Papyrus §739–750	Commiphora/ myrrh (soothes gums and toothache); Castor oil (base)	Commiphora: Chemically Attested pre-unification; Castor: 4000 BCE
ENT / Ear Treatment	c. 1550 BCE textual	Ebers Papyrus §764	Balanites aegyptiaca (balanos oil, primary ingredient for impaired hearing)	Balanites: 3600 BCE (HK43 Burial 333); 4450–3942 BCE (Uan Muhuggiag, corridor Node 3)
Surgical Trauma / Fractures / Burns	c. 3000–2500 BCE (Edwin Smith source; Qau trepanation skull c. 2181–2160 BCE)	Edwin Smith Papyrus (48 trauma cases)	Castor oil (wound dressing base throughout trauma cases)	Castor: 4000 BCE
Toxicology / Snakebite / Venom	c. 450 BCE textual; pastoral knowledge of venom management predates writing	Brooklyn Papyrus (snakebite, scorpion, tarantula); Ebers (animal bites)	Senna-related compounds; Henna (antimicrobial wound treatment); Balanites (wound wash, antimicrobial)	Henna: 3400 BCE; Balanites: 3600 BCE; Senna: Chemically Attested 3150 BCE
Hair Care / Scalp Health	c. 1550 BCE textual	Ebers Papyrus §437–476 (dedicated hair chapter)	Castor oil (hair growth in women); Henna (anti-lice, anti-dandruff, antimicrobial scalp treatment)	Castor: 4000 BCE; Henna: 3400 BCE

Domain	Source Material Date	Primary Papyrus	Corridor Plants Documented	Earliest Physical Evidence in Egypt
Perfumery / Aromatics	Kyphi: Pyramid Texts c. 2400–2300 BCE (named without recipe); recipe: Ebers 1550 BCE; Ptolemaic temples	Kyphi formula (Ebers, Harris Papyrus, Edfu and Philae inscriptions)	Balanites (primary carrier oil); Moringa (second carrier); Commiphora (Mendesian formula); Cymbopogon schoenanthus (kyphi); Castor; Henna (Cyprinum formula base)	Balanites: 3600 BCE; Castor: 4000 BCE; Henna: 3400 BCE; Commiphora: Chemically Attested pre-unification
Soap / Hygiene / Textile Cleaning	210 BCE earliest textual record; pastoral use predates writing	Egyptian administrative text c. 210 BCE (castor + natron bleaching); traditional use continuous	Balanites (saponin surfactant, soap substitute Mauritania to Egypt); Castor + natron (proto-soap); Henna (antimicrobial skin/body protection)	Balanites: 3600 BCE; Castor: 4000 BCE; Henna: 3400 BCE
Embalming / Mummification	c. 4500–3350 BCE physical (Mostagedda, Jones et al. 2014); Pharaonic peak: same proportions preserved 3000 years	Mostagedda wrappings (pre-dynastic); Saqqara workshop (26th Dynasty, Nature 2023); Papyrus of the Embalming Ritual	Castor oil (head treatment, Saqqara 2023); Henna (confirmed mummification material); Commiphora/myrrh (antiu compound); Moringa (luxury unguent); Balanites (carrier oil)	Mostagedda aromatic extract: 4500–3350 BCE (compound-class, Jones 2014); Castor: 4000 BCE; Henna: 3400 BCE; Balanites: 3600 BCE
Pest	c. 1550 BCE	Ebers Papyrus	Balanites	Balanites: 3600

Domain	Source Material Date	Primary Papyrus	Corridor Plants Documented	Earliest Physical Evidence in Egypt
Control / Vector Management	textual	(flies, rats, scorpions); Brooklyn Papyrus	(molluscicidal, schistosomiasis and guinea worm vectors, Molla et al. 2013); Castor (insecticidal properties); Senna (vermifuge)	BCE; Castor: 4000 BCE; Senna: Chemically Attested 3150 BCE

Sources for source material dating: Book of Hearts 3400 BCE — Bou Khalil and Richa (2014), American Journal of Psychiatry 171. Ebers Papyrus §856a First Dynasty reference — internal evidence, quoted in Nunn (1996, Ancient Egyptian Medicine, British Museum Press, p. 31); consistent with the Grundriss der Medizin der alten Ägypter (von Deines, Grapow, and Westendorf 1954–1973). Edwin Smith source text c. 3000–2500 BCE — Pommerening (2014) genre classification of Old Kingdom medical teaching texts; Qau trepanation skull c. 2181–2160 BCE (Fujita, Lee, Hong and Shin 2025). Mostagedda predynastic embalming recipe 4500–3350 BCE — Jones et al. (2014, PLOS ONE, PMC4132097). Papyrus rubric numbers follow Wreszinski (1912) and Ghalioungui (1987).

10. Predictions

The following predictions test the corridor-transmission hypothesis against evidence, existing or not yet gathered. Most draw on findings already established elsewhere in this paper, restated here as discrete, individually falsifiable claims rather than as part of the continuous argument; a smaller number are genuine forecasts — specified precisely enough that a future test could return an answer this paper's own model did not assume. Each prediction states its discriminating weight: how much a positive or negative result would actually move confidence in the corridor model, as distinct from merely being consistent with it either way.

Prediction 1

Knowledge source identified as pastoral. Confirmed: Haimov-Kochman et al. (2005, EJOG 123(1)): 'obtained probably by herders of domesticated animals.' This is independent confirmation: a reproductive-medicine paper, unconnected to this hypothesis or to Egyptology, reaches the same conclusion from its own evidence. The underlying mechanism and the pastoralist knowledge-pattern are independently corroborated by 2018–2022 veterinary-science and ethnoveterinary literature (Section 4). High discriminating weight.

Prediction 2

Systematic palaeopathological analysis of the Messak Settafet and Nabta Playa faunal assemblages, using the methodology of Van Neer et al. (2015) at Hierakonpolis, would identify

healed fractures in domestic cattle consistent with sustained veterinary intervention. The assemblages exist and are confirmed adequately preserved (di Lernia et al. 2013, PLOS ONE, e56879, for Messak Settafet; Wendorf and Schild 1998 for Nabta Playa cattle remains; di Lernia et al. 2024, PLOS ONE, DOI: 10.1371/journal.pone.0310739, confirms comparable bone preservation at Takarkori) but have not yet been examined for this specific evidence. This test requires no new excavation, only laboratory analysis of existing specimens. High discriminating weight.

Prediction 3

Corridor plants with pre-unification physical or chemical evidence in Egypt. Confirmed physical or chemical evidence (7): Castor oil (Egyptian tombs 4000 BCE), Henna/Lawsonia (HK43 Burial 16 physical hair specimen, Fletcher 1998, c. 3400 BCE), Colocynth (Naqada seeds 3800 BCE), Balanites (HK43 Burial 333, 3600 BCE), Doum palm (Predynastic tombs), Senna (Abydos herbal wine residue 3150 BCE, compound-class level, McGovern et al. 2009 note identification 'not yet conclusive'), Commiphora africana (aromatic plant extract consistent with Commiphora identified at compound-class level in Badarian/Naqada period wrappings at Mostagedda, Jones et al. 2014, PLOS ONE; Chemically Attested, not Confirmed, since species-specific archaeobotanical identification at a named pre-unification site is still pending). Old Kingdom corridor arrivals with transmission inference (2) and late post-unification trade arrivals (3) complete the inventory (full plant names, dates, and evidentiary detail in Section 6). These are small counts drawn from a denominator of 21 pre-unification taxa, and no null expectation for corridor-distributed representation has been independently calculated; the discriminating weight below reflects direct evidentiary strength, not a statistically tested departure from chance (see Section 6 for the full caveat). High discriminating weight.

Prediction 4

Medical evidence at Hierakonpolis in predynastic window. Confirmed: HK43 fracture healing; Mills (1992) antibiotic grain storage. High discriminating weight.

Prediction 5

Formal physician tradition begins at unification. Confirmed: Bestetti et al. (2024): shamans → Sem priests → Priests of Sekhmet. Moderate discriminating weight.

Prediction 6

Cult presence at Sais in the predynastic period. Confirmed: Naqada II epigraphic attestation (c. 3600–3350 BCE) of Neith worship at Sais, western Nile Delta. The later tradition of Sais as a dedicated medical teaching centre for obstetrics and gynaecology is well documented from the Middle Kingdom onward but is not independently confirmed for the predynastic period itself (see Table S2); this prediction is therefore scoped to the confirmed cult presence, which establishes Sais as the Lower Egyptian destination point of the corridor's geographic range. Moderate discriminating weight.

Prediction 7

A systematic survey of surviving Pastoral Period rock art panels across the corridor, using the player-posture identification methodology of Kumbani and Díaz-Andreu (2024, 'The art of music: the representation of musical instruments in the rock art of Zimbabwe,' Azania: Archaeological

Research in Africa, DOI: 10.1080/0067270X.2024.2415211), would identify lute-type instrument depictions at one or more corridor nodes. No such survey has been conducted to date; the existing record — the Tassili dance scene (Lhote 1958) and the multi-period Ti-n-Anneuin assemblage before its 2009 destruction — has not been examined specifically for instrument content. Moderate discriminating weight.

Prediction 8

If the cosmological naming logic documented for Commiphora africana (um el barka, 'mother of blessing') reflects a genuine transmitted pattern rather than an isolated case, the same umm-/mother-construction should appear in the corridor vernacular names of other corridor plants — Balanites aegyptiaca, Ricinus communis, or Lawsonia inermis — documented in the existing ethnobotanical literature (Burkill 1985 and successors), and where present, should correspond to an independent divine-origin narrative for that plant in Egyptian religious texts. This is desk-testable, requiring no new fieldwork, only systematic cross-referencing of existing vernacular-name catalogues against Egyptian mythological sources. Low–Moderate discriminating weight (contextual, not load-bearing; see Section 7 epistemic scope).

Prediction 9

If the corridor's shared application-domain pattern — the same plant used for the same conditions across the corridor and in Egypt — reflects genuine knowledge transmission rather than convergent independent discovery, the specific-application matching documented for Commiphora africana between the Sudanese pharmacopeia and the Egyptian medical corpus (inhalation, wound treatment, oral health) should extend to the other six corridor plants when checked systematically against existing Sudanese ethnobotanical surveys (University of Khartoum 2025 and comparable sources). This is desk-testable using existing literature. Low–Moderate discriminating weight (contextual; see Section 7 epistemic scope).

Prediction 10

Sekhmet associated with Lower Egypt. Confirmed: Coffin Texts. Moderate discriminating weight.

Outstanding Testable Prediction

The following prediction specifies the fieldwork that would most directly test the corridor model at its western terminus.

Prediction 11

If future palynological analysis or phytolith extraction from the Holocene playa lake deposits of the Richat Structure's central depression identifies Commiphora pollen or plant silica bodies dated to 6,000–3,000 BCE, this would confirm Commiphora's presence in the Richat zone during the proposed pastoral migration window. If organic residue analysis (GC-MS) of Holocene pastoral pottery from the Richat area identifies Commiphora terpenoid signatures, this would constitute direct evidence of harvesting and use by pastoralists. A positive result on either test would establish the Mauritanian confidence class for pre-3000 BCE knowledge as High, resolving its current Untested status; a negative result, replicated across multiple sampling sites, would weaken the case for a Richat-specific origin without falsifying the broader corridor model (Section 11). This is the paper's highest-priority recommendation for future fieldwork. Moderate discriminating weight.

This prediction identifies the fieldwork target at the corridor's western terminus. Analogous palynological and archaeobotanical survey predictions apply across all corridor nodes during the proposed migration window (3800–3100 BCE): at Tassili n'Ajjer, direct archaeobotanical sampling of the pastoral occupation layers; at Takarkori, targeted residue analysis of additional pastoral pottery contemporaneous with the Salem et al. 2025 genome individuals; and at Nabta Playa and Gilf Kebir, survey for botanical macro-remains at documented pastoral campsites. The Richat zone is currently the highest-priority target due to the absence of any existing botanical survey, but the prediction framework applies westward to eastward across the full corridor.

11. Alternative Explanations

The state-invention model does not straightforwardly account for the inversion. If medicine were invented by the unified Dynastic state, the expected trajectory would show increasing sophistication over time; the documented trajectory runs in the opposite direction. The Ebers Papyrus's own internal evidence (copied from older rational sources) contradicts this account from within.

Independent Nilotic development is possible but does not fully account for the botanical distribution under current evidence. Thirteen plants with North African corridor-zone distribution appear in the oldest Egyptian medical texts. Six are documented in the contemporary Mauritanian pharmacopeia. Commiphora was not native to Egypt. The doum palm's distribution runs from Mauritania to Egypt. On its own, ecological co-occurrence does not distinguish independent discovery from transmission — discovering a locally available plant's uses is a normal process available to any population living in its range, not evidence unique to this hypothesis. What discriminates between them here is the discriminating-test framework applied in Section 9: the cognate adr- root persisting across six corridor populations (Section 7) and the deep Saharan lineage continuity Salem et al. (2025) document from Taforalt through Takarkori, whose Maghreb/western-Sahara branch (Saharawi populations; Serra-Vidal et al. 2019) is ethnolinguistically continuous with the Mauritanian population documented botanically here, though not yet directly tested against it (Section 9). Independent Nilotic development offers no account of why the corridor population itself is linguistically coherent as a single group along this exact route, or why an isolated Saharan genetic lineage persisted along that same route at all — a coherence that does not bear on Egypt directly, but is the necessary premise for a population able to carry knowledge there at all, and one that a purely local Nilotic development has no reason to predict.

Mesopotamian transmission is not consistent with the North African botanical distribution documented in the oldest Egyptian texts. The plants in the oldest Egyptian texts are African in distribution. Current documentation of the Kahun, Ramesseum, and Edwin Smith plant lists shows no Mesopotamian botanical correspondence; this absence reflects the current state of the comparative record and is not itself treated as falsification (Axiom 5).

The pre-3150 BCE archaeobotanical evidence — plants documented before any state-level trade network — creates a chronological problem for the trade-route model, although absence of documented networks before that date does not rule out informal exchange mechanisms. Castor oil in tombs at 4000 BCE and colocynth seeds at Naqada at 3800 BCE predate any documented North African trade network at the required scale.

The Equifinality Matrix below makes these alternatives explicit for each class of evidence and specifies what discriminating evidence would look like. Quantitative thresholds and specific test

conditions for the discriminating evidence are detailed in Section 10 (Predictions); the matrix summarises the types of evidence that would favour each explanation. The purpose is to demonstrate that the transmission hypothesis is preferred not merely because it is consistent with the evidence, but because the alternatives face specific evidential problems that transmission does not.

1. Pre-papyrus plants in Egypt 4000–3000 BCE *(castor, colocynth, probable senna)*

- ***A. Independent invention:*** *Plausible. Nile valley populations could have independently identified medicinal uses.*
- ***B. Saharan trade network:*** *Possible for some. Predynastic long-distance exchange networks are archaeologically documented: baboons from the Horn of Africa appear at Hierakonpolis by c. 3700 BCE (Van Neer et al. 2004); the glyptic continuum documents elite exchange across Egypt, A-Group Nubia, and southern Palestine from Naqada IId onward (Hill 2016). These networks moved high-value prestige goods through elite acquisition channels. However, a multi-plant medicinal suite of pre-unification corridor species with consistent pastoral applications across the corridor is not a prestige import pattern. Trade is not ruled out for individual species but is less parsimonious than population movement for the full suite.*
- ***C. Corridor transmission:*** *Consistent. Plants arrive with population during 3800–3100 BCE Shemsu Hor window, preceding state formation.*
- ***Discriminating evidence:*** *Naqada I–III sites with multiple corridor plants together in a single context (e.g., three or more taxa in the same tomb or occupational layer). Multi-plant suites support C; single-plant finds or dispersed occurrences across different sites and periods support A or B.*

2. Commiphora africana: *non-native to Egypt, Sahel-zone origin, in oldest rational texts*

- ***A. Independent invention:*** *Weak. Commiphora does not grow in Egypt; Egyptian populations could not independently discover a plant unavailable locally.*
- ***B. Saharan trade network:*** *Possible. Long-distance resin trade is documented in the ancient Near East.*
- ***C. Corridor transmission:*** *Consistent and strong. Non-native plant in oldest rational texts; carried by a population traversing its habitat zone over generations.*
- ***Discriminating evidence:*** *Pre-3000 BCE resin trade documentation in the Nile Valley (e.g., Commiphora resin in a securely dated pre-3100 BCE context outside the corridor's known pastoral sites). If trade predates the corridor integration window, B gains support over C.*

3. Seven corridor plants in Mauritanian pharmacopeia *(Yebouk 2020, 2026; Boune 2025; Thouzery 1997)*

- ***A. Independent invention:*** *Consistent. Saharan plants used across a wide range by many populations independently.*
- ***B. Saharan trade network:*** *Consistent. Trading populations would retain knowledge of traded goods.*

- ***C. Corridor transmission:*** *Consistent. TEK continuity in a pastoral population that did not migrate east retains the original corridor pharmacopeia.*

- ***Discriminating evidence:*** *Palynological or residue evidence of the same plant suite at Holocene Richat-zone sites (Prediction 11). Shared suite across western and eastern corridor nodes discriminates C from A.*

4. Chronological inversion: *oldest texts most rational*

- ***A. Independent invention:*** *Unexplained. State-invention model predicts increasing sophistication; documented trajectory runs opposite.*

- ***B. Saharan trade network:*** *Does not address. Trade transmits goods, not knowledge systems; cannot explain the inversion.*

- ***C. Corridor transmission:*** *Explains. Inherited pre-state empirical knowledge acquired ritual framing as state theology absorbed it over centuries.*

- ***D. Differential preservation:*** *Partially addresses. Reeves (2008) proposes that rational texts were preserved as scribal curriculum while magical texts survived in less accessible temple contexts, which could produce an apparent inversion without any real change in the underlying tradition over time. This does not fully account for the pattern: Chester Beatty VI (c. 1200 BCE) is purely rational, showing rational-register composition continued into the Ramesside period rather than being confined to the earliest texts, which a pure preservation-bias account does not predict. A single counterexample does not disprove a general preservation bias, but it weakens the claim that the surviving rational texts are simply an early-period sample. This is consistent with a broader pattern documented independently of the rational/magical prescription count used here: Pommerening's (2020) genre-wide classification of Egyptian medical "teaching texts" (Lehrtexte), based on internal patterns of reasoning rather than the rational/magical distinction, traces this rational-register composition tradition from the 5th/6th Dynasty (c. 2400 BCE) through the Second Intermediate Period and early New Kingdom (c. 1550 BCE), with later instances of the genre — including Roman Period copies — tracing back to earlier compositional dates: evidence that rational-register composition was an ongoing scribal tradition across more than 2,000 years, not an artefact confined to the earliest surviving texts. This is a different genre classification than the prescription-level rational/magical count central to this paper's argument, so it does not itself settle the inversion question, but it independently weakens the premise that rational composition was a one-off early phenomenon later overtaken by magical framing.*

- ***Discriminating evidence:*** *Systematic magical-content classification using Grapow, Ritner, and this paper's count across the full papyrus corpus. If inversion disappears under alternative classification, the anomaly is reduced. A systematic survey of rational-register composition dates across the full corpus, rather than reliance on single counterexamples like Chester Beatty VI, would further discriminate C from D. Pommerening's (2014, 2020) teaching-text genre classification is a step in this direction, though it classifies compositional reasoning patterns rather than the rational/magical prescription distinction itself, so a corpus-wide survey using that specific distinction remains the more direct test.*

5. Pastoral knowledge source: *Haimov-Kochman (2005) independently identifies herders as probable source*

- ***A. Independent invention:*** *Does not address. The study identifies herders as source, not indigenous Egyptian inventors.*
- ***B. Saharan trade network:*** *Partial. Trade implies herder contact, but trade does not require herder migration into Egypt.*
- ***C. Corridor transmission:*** *Consistent and convergent. Pastoral population is both the knowledge source (Haimov-Kochman) and the proposed migration vector (this paper).*
- ***Discriminating evidence:*** *aDNA evidence of Saharan corridor ancestry at Hierakonpolis pastoral contexts. Salem et al. (2025) provides the Takarkori anchor; Hierakonpolis aDNA would close the corridor-to-destination link.*

Conclusion: *For each class of evidence, the matrix shows what alternative explanations predict, where they face evidential problems, and what discriminating evidence would decide between them. The transmission hypothesis (C) is preferred not because it is merely consistent with the evidence, but because it faces fewer unresolved evidential problems across the full evidence set. No single column defeats the others; the case is cumulative.*

12. Falsification Conditions

1. Evidence that the rational medical tradition first appears in Egypt after unification (c. 3100 BCE) with no archaeobotanical or textual antecedents in the Naqada period. If systematic survey of Naqada I–III contexts (c. 4400–3100 BCE) yields no medicinal plant residues and no pre-unification medical instruments or contexts, the hypothesis that the pharmacopeia predates the state is weakened. The current archaeobotanical record (castor oil 4000 BCE, colocynth 3800 BCE, senna 3150 BCE) constitutes the evidence to be overturned.

2. Egyptian magical medical texts predating the Edwin Smith source text (c. 3000 BCE). If such texts were discovered, they would directly contradict the claim that the oldest surviving medical texts are the most rational, breaking the inversion pattern documented in Table 1 at its oldest point. The absence of such texts is not claimed as confirmation of the hypothesis—it is a boundary condition: the hypothesis predicts that the oldest written record would prioritise botanical content over ritual framing, but the oral incantation tradition is expected to have existed alongside it. The falsification condition tests the written record only.

3. Systematic palaeobotanical evidence demonstrating that the pre-unification corridor plants documented in this paper were not available to predynastic Naqada populations via ecological continuity with the corridor zone. The Tassili and Takarkori evidence already contradicts this for three of the confirmed pre-unification corridor taxa.

4. Evidence that Neith cult presence at Sais was established substantially after the Naqada II period (c. 3600–3350 BCE), which would undermine Sais's role as the corridor's Lower Egyptian destination point. This condition tests cult presence only; the later medical-institution tradition at Sais is not claimed as a predynastic fact and is therefore not a target of this falsification condition (see Table S2).

5. Ancient DNA evidence demonstrating that the predynastic Hierakonpolis population had no Saharan corridor ancestry component — specifically, Fst differentiation greater than 0.05 between Hierakonpolis samples and the Takarkori-anchored Saharan population (Salem et al. 2025), or evidence that Hierakonpolis derives entirely from Levantine/Nilotic sources with no Saharan ancestry component at the 95% confidence threshold of available aDNA methods. This

condition is testable with future archaeogenomic analysis of predynastic Hierakonpolis skeletal material.

6. Evidence that the corridor plants documented here were present in Egypt before the Shemsu Hor window (c. 3800 BCE) in non-pastoral, non-corridor contexts — for example, settled Nile Valley agricultural sites with no pastoralist material culture. Specifically: if Ricinus communis, Balanites aegyptiaca, Citrullus colocynthis, Lawsonia inermis, or Senna italica are confirmed in such contexts before 3800 BCE, the hypothesis requires revision. (Hyphaene thebaica is excluded, since its eastern Sahelian range already extends into Egypt; its early presence would not falsify the hypothesis for that plant.) A separate, timing-independent condition: if any corridor plant is confirmed native to Lower Egypt or the Nile Delta specifically — not Upper Egypt or Nubia, the corridor's own southern terminus — its presence is adequately explained by local availability and needs no transmission account. Senna demonstrates the principle already: Senna alexandrina is native to Upper Egypt and Nubia, not the Delta, which is why it keeps its corridor classification. This would weaken, not globally falsify, the hypothesis — proportionally, depending on how many plants turned out to be Delta-native.

7. Systematic palaeopathological analysis of the Messak Settafet and Nabta Playa faunal assemblages, conducted using the methodology of Van Neer et al. (2015), finding no healed fractures or other evidence of sustained veterinary care in the cattle remains. This would weaken the claim that corridor pastoralists practised the same sustained-care tradition later institutionalised at Hierakonpolis (Prediction 2), though it would not by itself falsify the broader corridor model, since absence of healed fractures in a sample is also consistent with a smaller or differently composed herd.

8. A systematic survey of surviving Pastoral Period rock art across multiple corridor nodes, using the methodology of Kumbani and Díaz-Andreu (2024), finding no lute-type instrument depictions despite adequate preservation and coverage. This would weaken the claim of deep pastoral musical-transmission continuity (Prediction 7); it would not fully falsify the claim given the documented destruction of the Ti-n-Anneuin assemblage and the general under-survey of the corpus for this specific content (Section 7).

9. Systematic cross-referencing of existing corridor ethnobotanical literature finding that the umm-/mother-naming construction and the Sudan–Egypt application-domain matching documented for Commiphora africana do not extend to the other corridor plants (Predictions 8 and 9). This would weaken the reading of these patterns as evidence of a shared cultural-cosmological framework, in favour of Commiphora being an isolated case; given this evidence is already scoped as contextual rather than load-bearing (Section 7), a negative result would not affect the paper’s primary evidentiary pillars.

10. Evidence that the same multi-domain pattern documented in Section 9 — a single plant’s simultaneous use across medicine, perfumery, hygiene, and embalming — is equally present in other ancient pharmacopeias (Levantine, Mesopotamian, or other non-corridor traditions) for plants with no corridor connection. If multi-domain use is common wherever a chemically versatile plant is available, regardless of transmission history, this would favour the ethnobotanical convergence explanation (Garnatje et al. 2017; Teixidor-Toneu et al. 2018) over the ‘unified knowledge system arriving intact’ reading, weakening Section 9’s central argument specifically.

This paper opened with an anomaly — Egypt's oldest medical texts are its most rational, and every later century adds more ritual, not less. The explanation proposed here is that Egypt did not grow more superstitious over time; it grew further from a pastoral pharmacopeia it inherited rather than invented, re-narrating an old knowledge system as its origin receded from memory. The evidence for where that knowledge came from converges across botany, genetics, language, and institution — but convergence is not proof. What would move this from hypothesis to finding is a single, specific, unglamorous act: a soil sample from the Richat Structure's own wadi beds, tested for pollen that has never been looked for. That sample has not yet been taken. Until it is, this remains what it was on its first page — a hypothesis, held to the same standard it asks of everyone else, and open to being proven wrong by exactly the kind of evidence it invites.

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Artificial Intelligence Use Disclosure

Claude (Anthropic) — Primary research partner and analytical reviewer. Used for literature synthesis, argument testing, citation verification, and document construction.

DeepSeek — Background literature gathering and hypothesis development, including the Sahara–Sahel–Nile Botanical Network constraint framework.

ChatGPT (GPT-4o, OpenAI) — External reviewer and adversarial framework testing. Used to stress-test the structural argument and identify logical weaknesses.

Gemini (Google) — Source verification and retrieval of verbatim passages from print-only sources.

No AI generated the underlying argument, sourced original evidence, authored interpretive claims, generated scientific data, or conducted laboratory or field analysis. All cited evidence derives from published, peer-reviewed sources. The analytical framework, editorial judgments, and conclusions are the author's own.